The Conceptual Foundations of Behavior Analysis

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Acknowledgment

Preface

My Part

This text evolved as the result of my desire to communicate all the things that students are typically left to learn the hard way. It's often said that until students blunder and make a painful error, they can't see the value of learning complex or subtle things that require many hours of homework, and they can't have the sophistication to accept things that are counterintuitive even if they are proven. As a result, students are often left to learn the hard way, as I was. I refuse to accept that the hard way is the only way.

That unacceptable "experience is the best teacher" approach is what it is because it's immediate consequence is actually easier for both the student as well as the faculty, even though in the long run it is surely the hardest and most painful way to learn. For the faculty, the burden of accountability is removed when it is claimed that the majority of a student's education occurs after graduation. For the student, the burden of studying hard enough to understand complex issues is removed by the claim.

This course accepts the challenge of covering complex material early in a student's career while the student is in graduate school. Its goal is to provide what is best in the long run. The immediate consequence on this text of accepting that something must be accomplished now, is that it requires that very complex and subtle issues be communicated in a way that is as easy to understand as possible to someone who does not already know how to conceptualize and organize the bewildering complexity of the behavior of organisms.

Your Part

Unfortunately, the immediate consequence of taking this course on the student is that it requires that they have a willingness to learn now what is necessary only in the future, and to work through complex and subtle issues now, as a student, when no one's life or research career depends on it. Only in that way, will it be possible to take the appropriate action in the future the first time it happens rather than the fifth or tenth time.

An important challenge facing students trying to accomplish their career goals is overcoming a widespread misunderstanding of the educational process. The fact is a text cannot make complex issues perfectly clear following a cursory read, nor can the faculty make issues understood simply by explaining them in a lecture to a class as a whole. Those are possible only in the most trivial high school or undergraduate courses. The material covered in this text is not trivial. Education does not work like Wal-Mart where you give the cashier some money and you get to take home a loaf of bread. Education works more like Gold's Gym where you pay the cashier money and what you take home depends on how hard **you** work at the task. No one can give you muscles or understanding but yourself.

The most pernicious impact of the misunderstanding of how education works is how it affects the time students allocate to actual studying. Just as sporting or

musical skills take many hours of practice so does academic understanding. Universities are structured around a 45-hour work week: 1 hour in a classroom and 2 hours of actual studying per week for each credit hour, given a 15-hour load. Lighter loads for graduate students translate to more time studying not more time off. These times do not include travel, getting ready, chatting with friends, or breaks. No one would be foolish enough to presume they could hold a musical recital or a skateboard exhibition after only a few hours of practice. The task is not to simply know the sequence of notes or to be able to balance on a board, but rather to do it well enough for someone to pay you to do it, or to hire you rather than hire some other candidate. It has been said that it takes 10,000 hours of practice to become good at something. That may or may not be true but it is certainly true that only a very little practice will result in only a very little skill.

It is worth a few moments reflection to consider that a 45-hour work week is not really that much; that it would be nearly impossible to not understand the material in this course if you spent 45 hours a week on academics; and it would be nearly impossible to have anything other than a successful career if you truly understood all your coursework.

I. Understanding Underlying Organizing Principles and a Metaphor for That Understanding

More than simply its history, or the principle of operant reinforcement, the meaning of behavior analysis is its way of partitioning what is real from what is not, what is real from psychobabble, what really works from what should work, and how to put that information into some systematic context that makes the information memorable and useful. As a result, the most important thing to understand in order to be a successful behavior analyst is the organizing principles, conceptual foundations, or "paradigm" of behavior analysis.

Unfortunately, the organizing principles or conceptual foundations of behavior analysis is often overlooked, misunderstood, or trivialized. The task is to **understand** the material, not to only repeat a bunch of vocabulary words. The task is to make sense out of nature and to see the fundamental processes that actually drive the behavior of organisms. Most untrained people are not up to the task. Most people see only the surface of what is around them: the buzzing mass of confusion. That's why they pay professional behavior analysts to shape their pets, their kids, and themselves.

This task of understanding the organizing principles of behavior analysis is much like coming to see an embedded object in a single image random dot stereogram (SIRDS) or “magic eye” picture. All the details are there; the task is to find and clearly see the organizing principle that brings order out of the seemingly random facts. Once you are able to see it, it’s apparent even with a casual glance, but before you’re able to actually **see** it, it is simply not there.

Possibly the best way to understand your task in this (and any other) course is

to examine this embedded picture metaphor in detail. Look at the following picture until you can see the embedded image.

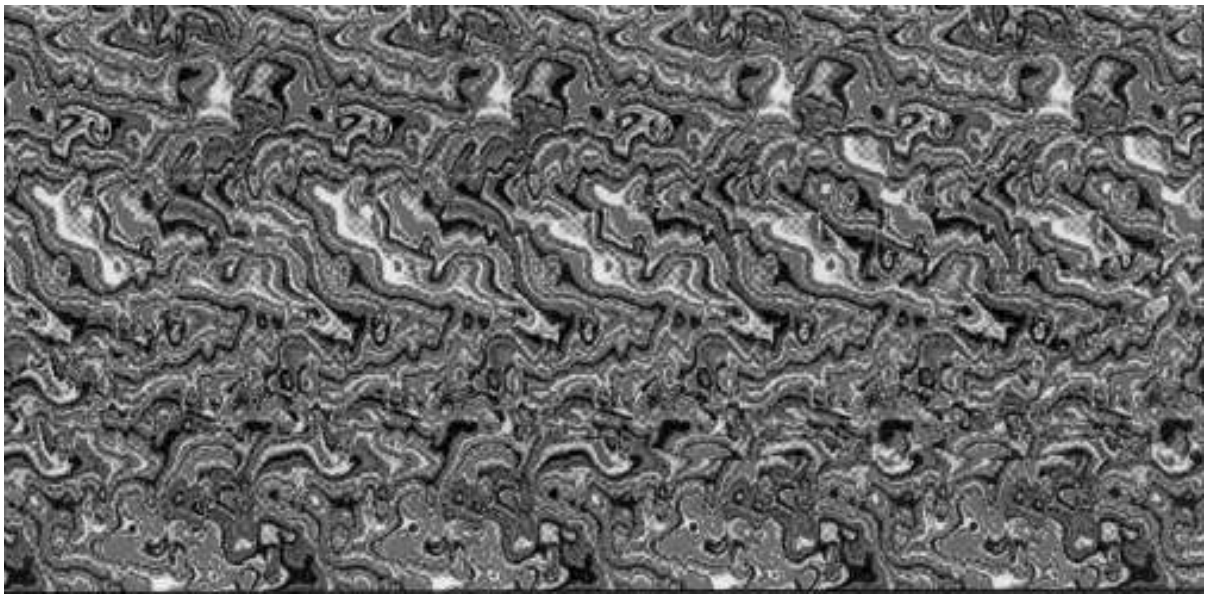

Figure P.1 A single image random dot stereogram illustrating that an organizing principle(the dolphin) can bring order to apparent chaos (the squiggly blobs). Secondly, it illustrates that there is a difference between simply being able to repeat the organizing principle and actually seeing or understanding it.

A. Issues Pertaining to Seeing a SIRDS: A Metaphor for Understanding Underlying Organizing Principles

1. To Simply Say Dolphin is Not the Same as to See the Dolphin

Someone simply saying "dolphin" when confronted with the picture in Figure P.1 may sound like the person sees what is in the image but that may not be the case. They may be simply repeating what they were told was in the picture.

Simply being able to repeat the definition of an emboldened word such as "reinforcement" in a textbook is not to understand how nature works nor to see how all behavior is a manifestation of fundamental processes. Understanding the processes in nature and understanding their application refers to your ability to behave appropriately to virtually all instances of the underlying process.

Understanding a functional relationship dramatically changes your ability to solve problems. It is analogous to knowing the general solution strategy of a video or card game; you do dramatically better if you actually understand how the game works. You will do dramatically better in your practice of behavior analysis if you actually understand its underlying processes. The remaining items in this list enumerate additional aspects of the metaphor. This entire text could be seen as an elaboration of the difference between "see" and "say" when it comes to behavior analysis.

There is substantially more involved in understanding behavior analysis than simply saying reinforcement in answer to a test question. Don't cheat yourself,

learn all that this course has to offer.

2. Not Seeing the Dolphin Does Not Mean That its Existence is Simply an Opinion

If someone does not see the dolphin, they could presume that everyone that claims to see the dolphin is delusional, or that the dolphin in the SIRDS is simply an opinion of many influential people who were told that there was a dolphin in the image but who are wrong, and that a different group of influential people could be assembled who say that there is a fire truck in the figure. This view is egocentric to a fault. It can be easily shown that a hundred or a thousand or even a million people can all identify exactly the same precise details of a totally novel figure in a SIRDS without having first been told what the image was. There is empirical proof that there is a dolphin in the image, it is not simply an opinion because someone or even thousands of people do not see it.

Similarly, the facts of behavior analysis are not simply the opinion of many influential people. Academic journals with their peer review system and open discussion go to great lengths to prove to even skeptics the validity of the information.

3. Seeing the Object is Important – Its Label is Inessential

Being able to see the dolphin and identify its characteristics is the important thing. Calling it a dolphin, or a fish, or a pointed thingy with a flapper in the back matters only a little.

Understanding the boundaries of a concept or how a process works is critical; additionally, knowing the label for the set or process is only useful for communicating to other people who already understand the same thing.

4. The Baseline is Not the Total Absence of Anything to Say About Dolphins

There is a difference between someone who can describe what they actually see in the picture and someone who says nothing because they can't see anything in the picture.

There is also a difference between someone who can describe what they see and those people who see nothing, but having been told that there is a dolphin in the picture, can extemporize with confidence at great length about dolphins from what they have been told earlier. The difference between the statements of someone who actually sees the dolphin in the SIRDS and someone simply “winging it” and only talking about what they can remember or make up about dolphins is consequential. One is anchored in reality and is correct, while the other has only a coincidental relationship with the details of the specific dolphin embedded in the picture.

Just because someone can expound with great confidence and charisma about psychology does not mean that they correctly understand it or that they can

correctly use their knowledge. The absence of something to say about psychology is not the only sign that the person is ignorant about the topic. Everyone has, and expresses, an opinion on psychology. Professional psychologists must do significantly better than amateurs at predicting and controlling behavior. People can get talk-show quality advice for free.

5. The Dolphin Cannot Be Pointed To - It's Not a Simple, Immediately Apparent Object Like an "X" on a Chalkboard

The dolphin in the picture is not an object that can be held in the hand, nor does pointing to it or tracing its outline automatically enable someone to see it.

Similarly, a fundamental process of nature is not an object or a vocabulary word, but rather it is a specific set of relationships between arbitrary objects embedded in noise. It is a process; it is how things work. It is not simply a point of view. For example, reinforcement is an abstract relationship between arbitrary behavior and functional consequences. The behavior can be key pecking, saying hello, or a career of helping people; the consequence can be pieces of corn, a smile, or being categorized by colleagues into the same group as Gandhi. Reinforcement is not best understood by conceptualizing it as the subject realizing what needs to be done in order to get the reward nor activity in the hypothalamus. It's a probability increase in a behavior that is attributable to the consequences of that behavior. The differences in these conceptualizations is subtle but of very great consequence.

6. Seeing the Dolphin Is Not Something a Person Can Give You

Coming under the control of the dolphin rather than the surface features of the SIRDS is a complex behavior acquired by an individual by their own interaction with the picture and is not something someone can give someone else.

No teacher can simply say words to a student and thereby enable the student to understand nature from then on. No teacher can simply say words to a student and thereby enable the student to play a piano from then on.

7. It Takes Active Practice and Time to See the Dolphin

The ability to see the dolphin, build muscles, and play a musical instrument can only be accomplished by the individual working at it themself.

Understanding the machinery underlying peoples' behavior cannot be given to someone through words in the absence of work on the part of the student.

It takes time, active practice, and feedback from nature to:

- see a fundamental process (such as reinforcement) everywhere and
- to immediately think of those fundamental processes when a new specific problem arises.

8. To the Degree That a Person Believes That an Outline Pointed to is Seeing the Dolphin, It Damages Their Ability to Actually See the Dolphin

It is obvious that a person hopelessly misses the point if they say: "I don't want to fool around trying to see what is in the picture - tell me what to say - it is my right as a student paying for this class." Similarly, a teacher drawing a heavy line outlining the dolphin misses the point.

If a person understands no more than the textbook definition of reinforcement, then they will have difficulty coming to see how ubiquitous reinforcement is in nature and how it actually is the cause of most things people and other animals do. A person limited to a textbook definition will be slow to see reinforcement in the interaction between a mother and child and will be less likely to be able to give people the ability to behave appropriately.

9. People Who See the Dolphin See a Different Picture Than People Who Don't See the Dolphin

Professionals see a different world than amateurs. This is true in art, sports, music, and psychology. Whereas the laity public sees heroes, criminals, and willful children; professionals see people with different reinforcement histories. Whereas the laity see immutable personalities; a professional sees a baseline behavior against which interventions can be evaluated. Whereas the laity see in a person's behavior the expression of the inner person; a professional sees the behavior as being the result of the person's life experiences. Whereas the laity see the task of therapy as convincing the inner person to want to do right; the professional sees the task of therapy as giving the person life experiences which reliably change the probabilities of classes of behavior to classes of stimuli.

10. If You See the Dolphin, You Know How Each Piece Relates To Every Other

If you understand a fundamental process, you are able to use facts in flexible, novel ways, and are able to understand how totally novel things interact; you are said to be fluent in the area. It's important to note, however, that the reverse is not true. Just because someone has a ready answer for a problem doesn't mean that they understand the solution. Recall the prior example of a person who could extemporize about dolphins without seeing it.

11. There Is Satisfaction in Coming to See the Dolphin in the Apparently Random Image

It is a wondrous and exciting experience to realize that you understand important things about how nature actually works and that you can do things with that knowledge.

12. A Blind Person or a Person With Only One Eye Cannot See the Dolphin

Some people may never be able to understand the fundamental processes driving nature. Many people cannot pass their field's competency exam such as the bar or the BCBA, many people cannot publish a research paper, and many people cannot shape an animal to do a specific behavior. But, simply saying: "I just cannot do it" does not give wisdom nor does it give the right to be an incompetent psychologist. For example, would you let a surgeon who was a nice person cut into your brain Who said "I love doing surgery but I can never get it back together right. It's just too difficult for me to understand.

13. Teaching People to Only Say Dolphin is Brainwashing

Brainwashing is teaching people to repeat words on authority whereas education is enabling people to understand how things work and enabling them to prove why things work that way. In that sense, simply saying dolphin is opinion and superstition and flag following, while seeing the dolphin is fact, science, and being educated.

B. Pedagogical Points Illustrated by the SIRDS Metaphor

1. Incorrectly Identifying What is in a SIRDS is Wrong Regardless of How the Error Occurred, and Nothing is Exculpatory

Typically, people gain their knowledge of nature via a text, journal article, or lecture. For expositional simplicity, these sources could be collectively defined as "the teacher". The teacher is typically presumed veridical even though it is not necessarily the case. For example, if a teacher, who does not see the dolphin, lectures that a fire truck is in the SIRDS, then that does not turn the dolphin into a fire truck nor prove that the contents of a SIRDS is simply a matter of opinion. It does not make "there is a fire truck in the SIRDS" the correct answer anywhere but within that mistaken teacher's classroom.

Some students put an issue behind them once they pass a course on a topic. They erroneously believe that if what the teacher taught them was wrong, or if the material was not on the test, or if an answer was graded as correct; then pointing out that exculpatory evidence will exonerate them of any errors they make. Obviously, that is simply not true.

For example, if a teacher tells you a gun is empty, and they were wrong, and you point that gun at someone and pull the trigger, you will cause harm to your target. The facts of the matter are: being told information does not turn the statement into a fact. Even if the source is your teacher, acting on an error can have a bad consequence on you, your research program, or your patient that nothing can fix. Finally, you are responsible for your errors and nothing can absolve you from blame.

Would you submit to brain surgery by a physician who did not understand brain anatomy and physiology, but who had a court order saying that they did not have to know that information as well as other surgeons? The fact is, neither an

assigned grade of A nor a court order; nor a memo from a dean excusing a student from a class because they are on the football team; can give someone the skill to correctly publish a paper, manipulate someone's behavior, nor the moral right to try.

Unfortunately, a non-trivial amount of the information being taught at universities is wrong. There are three ways that a teacher could come to be wrong.

a. Teacher Was Taught the Wrong Thing by Their Teacher When They Were a Student

Suppose a student attended a psychology department where that student's mentor as well as most of the other faculty in that department believed that penis envy and id ego conflict were the organizing principles underlying all human psychological phenomena. Metaphorically, those faculty had all been taught to say fire truck when looking at a SIRDS with a dolphin in it. This error is possible when neither the teacher nor the students ever saw the dolphin. A mentor with that training would teach future teachers to chant: "there is a fire truck in the picture." These hapless students would graduate and enter their profession feeling good about their understanding of nature but would be, in fact, incompetent because there is not a fire truck in the picture but rather a dolphin. The fact is that the fundamental process driving behavior is not penis envy but rather reinforcement.

b. Teacher Didn't Actually Understand When They Were a Student

Modern education is evolving into too often teaching by giving lectures and too often evaluating students based on what they choose on a multiple-choice test or in a short answer test. It should be apparent that a teacher simply saying that there is a dolphin in a picture is not teaching and that a student subsequently simply choosing the alternative "a dolphin" on a multiple-choice test does not demonstrate understanding. Unfortunately, in too many cases it is possible for students to graduate and become teachers themselves without ever understanding the paradigm they profess.

c. Teacher Became Enamored by an Area They Don't Actually Understand

The occurrence of an incompetent teacher can also occur when a teacher teaches in an area they became enthusiastic about, but for which they were not trained, tested, and corrected by mentors who were experts at understanding the subtleties of how the paradigm actually works.

The amateur teacher may have had an insight about something outside their actual field. Metaphorically, they are convinced that they see a fire truck in some other field's dolphin picture and that all the prior researchers who thought that there was a dolphin in the picture were in error. The amateur teacher may very well be right but they could also be wrong. This type of error can occur because to this teacher mindlessly repeating the word fire truck makes as much sense (or

more) than mindlessly repeating the word dolphin. Unfortunately, this false sense of superiority is often accompanied by an equally false sense of understanding the field. The students of these novices cannot provide much in the way of corrective feedback when they themselves don't understand the area. Additionally, the students don't have the authority or confidence to say "that statement is false" or "that statement is not paradigmatically correct."

Only peer review is up to the task of evaluating substantive corrections of paradigmatic statements and is one of the reasons that a publish or perish requirement is a policy at most tier one universities. While the policy may inhibit some new and correct ideas, it serves the important function of limiting the proliferation of bad ideas. In situations where peer review is absent, a teacher who never received training in the subtle and complex aspects of a discipline may come to truly understand that discipline on their own, but on the other hand, they may fail to adequately understand it. It takes very little to be able to say some basic aspect of a field. That does not mean the speaker understands the intricacies of the entire paradigm of the field. Proper research is principled or paradigmatic. The research reveals how the natural world which resisted integration into the paradigm can in fact be seen as the result of paradigmatically consistent elements and processes, and that the adjustment accounts for more variance across a wider range of situations than the previous interpretation of the commonly accepted model.

d. Impact of a Teacher Who Is Wrong for Whatever Reason

When a teacher who does not understand how nature actually works, and teaches about fundamental processes to their students, any connection between their words and reality would be only coincidental. (Metaphorically, the hapless teacher uses a new stereogram with an embedded elephant in it but teaches students to say dolphin.) Imagine the impact on a student who actually saw the elephant when the only acceptable answer was "there is a dolphin in the picture." (Recall that the teacher had only learned to say dolphin rather than having actually learned to see what was actually in the stereogram.) Pity the poor students who saw the elephant correctly!

2. Pedagogical Dilemma: Teaching the Label for a Principle Could Block Learning the Principle

Teaching an "answer phrase" for a thing, such as pointing to a SIRDS and saying "there is a dolphin in this SIRDS", and then evaluating the answer "there is a dolphin in the SIRDS" as correct, often has the unintended result of teaching the students to repeat that phrase without seeing the dolphin or even trying to see it, leaving the student with no ability to make sense of other SIRDS. The negative consequences of this faulty teaching approach have led to the fundamentally wrong-headed teaching approach of refusing to specify what is in the SIRDS so that the students must emit whatever behaviors are necessary to come to see the dolphin and allow the test to differentiate students who see the

dolphin from those who do not have that skill. While implementing this cynical approach makes the simplistic test question "what is in the SIRDS" more valid, it does little to help students to come to see the dolphin.

The other half of the coin is the equally erroneous, and equally self-serving cynical belief on the part of many students that the perfect teacher should be able to explain even complex things so well that students would immediately understand them in the absence of any effort on the students' part. This view is as preposterous as asserting that a good music teacher would enable a person to play the piano in a few minutes by simply correctly pointing out which notes to press and when, or that a good biology teacher could produce muscles on someone simply by correctly describing how the body makes muscles.

The present text will attempt to steer between these two erroneous perspectives.

C. A List Can Provide Only a Disembodied Fragment of the Actual Organizing Principles of Behavior Analysis

It takes this entire text to develop the conceptual foundations of behavior analysis. Understanding an organizing principles is a higher order behavior and is not simply mindlessly repeating some of the facts of a situation nor simply repeating the words summarizing the organizing principle. What behavior analysis is, requires: an understanding of what it considers real and why; what is considered a meaningful explanation and why; what covariance is considered essential for understanding; and how that knowledge can be generalized.

Simply put, behavior analysis is a complete "paradigm": it's a way of thinking and its conceptual foundations must be understood.

1. Behavior Analysis is a Way of Organizing the World

Each of the following characteristics of Behavior Analysis is an essential aspect of the worldview labeled Behavior Analysis or Radical Behaviorism in the same way that both hydrogen and oxygen are essential elements making up water. Without all the requisite elements, it is simply not Behavior Analysis. Additionally, adding incompatible elements changes the worldview to something entirely different. Just as adding sulfur to hydrogen and oxygen results in sulfuric acid which is very different than water.

It takes this entire text, or even more, to develop the logic underlying, and the support for, a behavior analytic view. But, to preview the perspective:

a. Behavior Analysis is a Deterministic and Principled Science

With respect to its methodology, resulting knowledge, and explanatory system, Behavior Analysis is based exclusively on events in the natural world and is unreservedly committed to the view that all behavior is the result of a specifiable cause. Behavior analysis is deterministic. Behavior analytic explanations do not provide for divine intervention, free will, magic, or space alien control.

Additionally, behavior analysis, like any science is based on the realization that the enormous variety of phenomena in the field are the result of a limited number of fundamental processes interacting in a limited number of possible ways. Those processes and interactions have non-random results and those results follow specifiable rules. The view is that causation is reliable and that Euclidian like logic can be used to advance our understanding from fundamental research findings to statements of general principles of causation and expected results. This type of principled system also enables research to produce transitive knowledge which cumulates with each additional research finding.

As a principled science, behavior analysis first reduces the broadest possible set of behaviors to a minimum number of empirical externalistic functional relationships or processes (such as reinforcement and stimulus control). Those processes have defined properties. These systematic processes or principles are used to explain behaviors in the natural world, and to create a principled system with which to generalize or predict and under what conditions those behaviors will occur in the future.

In order to be meaningful, there cannot be any discrepancy between the occurrence of events in nature and principles. If there is a discrepancy either the event was misinterpreted or the principle is in error. If a principle is in error in one case, then its explanatory power is questioned in any application. To a principled science any discrepancy is of grave concern and the rationale underlying most research. To an unprincipled science (an oxymoron) a discrepancy between its processes and an event in nature is of no real concern, because principles can be eclectically and indiscriminately invoked as necessary for each different question even if they are contradictory.

b. Behavior Analysis Requires Objectively Demonstrated Entities and is Therefore Strictly Externalistic

For the same reason that a judicial system must move away from convictions based on the intuition of the prosecuting attorney to decisions based only on provable facts; so too must any system of psychology move away from the intuitions of its practitioners to decisions based only on proven facts. The goal of a judicial system or science is to entirely remove personal opinions and intuitions from the decision process. Only in this way can the field be practicable, only in this way can the field be sure of always moving toward the truth, and only in this way can the field be ethical.

If something is not known to be true, it is excluded from the knowledge base. It's rather like wanting to be sure that a jug of water is not contaminated before pouring it into the cistern containing your only drinking water. Additionally, meaningful communication requires that the speaker and the listener necessarily have the same referent for the communication. Finally, if a disagreement or miscommunication occurs, then there must be a procedure for resolving the issue by way of a publicly available and failsafe procedure that inevitably results in a resolution that both sides would have to accept. If the discrepant view cannot be so proven then it cannot be considered a fact.

A serious impediment to progress in traditional Psychology has been the use of causal variables hidden inside organisms where they cannot be proven true or false and had to be accepted as is. As a result, facts were contaminated with opinions and psychology became less than what it could have been. For example, a Freudian could be asked to explain why a person smokes when that person says that they wish they could quit. Presumably the thing that is causing the person to talk (the mind) is the same thing that causes the person to smoke (the mind). The Freudian would simply retort that that proves the existence of an invisible subconscious inside the mind in order to justify the discrepancy between behavior and its putative control (the mind). Presumably if it could be shown that the subconscious also wanted to quit, the Freudian would simply say "oh wow, we have just discovered that humans have a sub-subconscious." Behavior analysis builds only on external objectively provable entities and eschews the creation of ad hoc explanatory actions, because things are not true simply because someone wants or needs them to be true.

Even if internal entities are proven true, Behavior Analysis does not consider internal explanations as the explanatory high ground. Rather explanations which specify external processes which control or predict behavior are considered the necessary and sufficient foundation for understanding behavior. For example: suppose you touch one end of a single neuron organism, which in turn activates the dendrite within, which in turn activates the axon, which in turn actives the muscle, which in turn moves the organism. From a behavior analytic perspective, "touching the organism made the organism move" is the specification of the cause or process that made the organism move. It is a sufficient and useful explanation because the relationship between the controllable environment and the measurable behavior of the organism is understood while the statement "the neuron made the organism move" is neither a necessary nor a sufficient explanation because it tells you nothing about the functional relationship between the controllable environment and the measurable behavior of the organism. "The neuron made the organism move" gives you nothing that would allow you to get the organism to move. "The neuron made the organism move" is in that sense useless information unless you are a biologist and are only interested in cell activity per se rather than how that cell activity came to be or what the final organismic output of that cell activity was. Behavior Analysis is about the behavior of the organism.

c. Behavior Analysis Establishes Explanations, Causes, and Meaning Via the Functional Properties of Objectively Demonstrated Entities

The most definitive aspect of the meaning of a thing is contained in the complete set of all observable functional relationships between it and the natural world.

For example, a smart phone, at one level is clearly an empirical physical object about 6 inches by 4 inches by ¼ inch, made of metal and plastic with one surface made of glass. From an internalistic perspective, it is an empirical central processing unit, with a graphical processor, memory, and input sensors and output

actuators. However, the most important and defining property of a smart phone is the empirical functional properties of its user interface. If you push "this" button, the phone turns on; if you touch "this" spot on the screen, a menu is displayed. Swiping the screen reveals additional options. Touching the blue spot displays a picture of you and a friend in Cancun. Sliding your fingers apart allows you to show the scorpion on the ground next to your foot just before it stung you. Additional user dependent functional relationships provided by the phone allow you to set your personal preferences for your user interface thus giving your phone its own enduring characteristic way of behaving to the inputs you give it (i.e., in that sense the phone can "learn" to have its own "personality.")

It takes only a moment's reflection to realize that virtually **the only thing anyone cares about are the external empirical functional properties of their phone. The internal hardware and software is irrelevant.** Even memory capacity and speed are only relevant in terms of how they change the behavior of the user interface.

This focus on factual external functional relationships rather than opinions about internal properties is also illustrated by the following anecdote. A Radical Behaviorist and a cognitive neuroscientist walked into a philosopher's bar. The bartender says "free drinks to whichever of you can best tell me why this herring gull retrieves eggs that roll outside the nest." The Cognitivist thought about what types of algorithms could result in egg retrieval and confidently said "when the egg position discrepancy detector is activated by an egg sufficiently out of position, it triggers the egg retrieval mechanism, and I can prove it. He then moved an egg in the nest 1/4 inch and the bird did nothing. He then moved it 1 foot from the nest and the bird retrieved it. He then smirked and said (a bit condescendingly) "and that's the way you do science my friends" because he was convinced he was clearly the winner. In point of fact however, the cognitivist said nothing more than what people already knew. When the egg gets sufficiently away from the next, the gull retrieves it. The cognitivist simply provided a synonym (the cognitive process) for what everyone saw the gull do. It was nothing more than a restatement of the question! The Radical Behaviorist made eggs of different sizes, shapes, colors, and patterns, and placed them different distance from the nest and determined how retrieval changed as a function of each. The behaviorist then stated the environmental conditions that trigger egg retrieval and those that did not and said to the cognitivist "you fail to understand science. You should try your explanation and proof on someone other than your students. Even a philosopher knows you don't have an explanation, you have nothing more than a tautology." Then the behaviorist passed one of his free beers over to the hapless pedant and said "try reading Skinner in the original some time."

Externalistic objectively demonstrated functional relationships are labeled processes when they have an effect on a dependent measure. In the egg retrieval example, a systematic characterization of how egg retrieval varied as a function of changes in the eggs would be labeled a causal process governing egg retrieval. As a second example, if a particular behavior is followed with a change in the environment such that the rate of that behavior increases, then that functional relationship between the behavior and the outcome is labeled the process of

reinforcement and in that sense the occurrence of the reinforcer causes the subsequent rate increase.

d. Behavior Analysis is Concerned with Understanding the Moment-to-Moment Changes in an Individual Organism's Semi-Permanent Adaptation to Covariance in the Environment That Emerges and is Lost Across the Seconds-to-Days Time Scale ("Learning")

Inanimate objects on a lifeless asteroid exist. The rocks lay on the ground and "just sit there" if some other lifeless asteroid crashes into the first asteroid then many of the rocks will be moved to a new location. Things that are not alive can be made to move and those movements can be characterized by, predicted, and explained by, the principled processes of Newtonian physics. The cause of the movement is the specification of the functional relationships involved.

A wide variety of changes can occur in a wide variety of entities as the result of a wide variety of processes. Changes across various levels of molarity and time scales are systematically presented, compared, and contrasted in Chapter 4 of the present text.

A fundamentally important form of adaptation and the focus of behavior analysis occurs when the response to a stimulus that an individual living organism makes is semi-permanently changed across the seconds to days time scale by the exposure to covariance between events in the environment. A specific example of this process is the well-known semi-permanent change in an individual pigeon's behavior by repeatedly presenting food presentation whenever it pecks, (i.e., Thorndikian reinforcement) or the semi-permanent change in an individual dog's behavior when a bell is repeatedly followed by meat powder (i.e., Pavlovian reinforcement).

Just how truly astounding this class of adaption is, can be easily illustrated. Suppose you walk up to a trash can and yell: "look out." It will just sit there. Suppose you do it 10 more times. It will just sit there all 10 times. Suppose you walk up to the trash can and kick it; it will slide across the floor. Suppose you do it 10 more times. It will slide across the floor all 10 times. There is nothing special about either inevitable unchanging and perfectly predictable outcome. Now suppose you correlate those two events: you walk up to the trash can, and yell lookout and kick it. The trash can will slide across the floor. Suppose you pair the events 10 more times – the trash can will slide across the floor the 10 more times you kick it. Then suppose you walk up to the trash can and only yell lookout. If the trash can then slid across the floor you would be shocked silly. It never moved when you simply yelled look out before.

On the other hand, if you had done the exact same procedure with a dog, you would not be surprised by it running away when you yelled even though the dog is made up of the same materials that were in the trashcan (i.e., organic compounds).

It is self-evident that the dog is alive and the trash can is not. Many processes across many levels of molarity and time scales were involved in organic matter evolving into an escaping dog; **BUT** a spoonful of magic, or "know-what-to-do", or

a space alien receiver is not among them.

The issue is: how to conceptualize exactly how does that individual dog come to "know what to do" in that specific situation. It must be what experiences cause the dog to run. Obviously it is not space aliens nor is it that the dog can read the future. Neither is it the case that the shout "look out" caused the dog to run, it did nothing during the preliminary ten presentations. Nor is it that dogs will run upon hearing "look out" 11 times. It's easy to show that a random relationship between "look out" and a kick will result in the dog simply disinterestedly laying there, for any number of shouts. The only correct answer is that a correlation between "look out" and a kick will result in running away to the warning. The cause of the running away is the correlation in specific external events. It is labeled reinforcement and short time scale adaptation.

The label for explaining the behavior of the dog as "the dog is alive and knows what to do" is a tautology and is **ignorance**. The label for the determination of the precise combination of external events that cause living organisms to react to environmental events across a relatively short time span is **behavior analysis**. In our example case, we are interested in understanding precisely what factors caused the dog to learn to run away to a shout. If "learning" is the organism's steering wheel, then behavior analysis is focused on what turns the wheel not whether the wheel is made from steel or plastic or whether there are gears or levers instantiating the adaptation. **For behavior analysis, the task is to document what environmental events cause what behavioral results.**

There are two important distinctions between the behavior of the trash can and the behavior of the dog. First the dog's behavior to the yell changes or adapts with increasing experience. Secondly, that adaptation endures for a short time even after the correlation with the kick is removed before disappearing. That is to say, the dog continues to run following the yell for a few trials even after you stop kicking it. Behavior analysis is focused on organismic adaptation with these two characteristics; those that occur across the seconds to days time scale, and those that are the result of the correlation of an event and a subsequent, functionally important, event.

An individual is seen as an entity that is, for the most part, a growing set of enduring characteristic and predictable new response patterns established by contingencies of functionally important events labeled reinforcers. As a result, understanding the effects of contingencies of reinforcement is the core of behavior analysis. Additionally, because the task is to understand how an individual's behavior adapts as a function of increasing experience, the exclusive focus is on the causes of the moment-to-moment changes in the behavior of an individual. The average behavior of a group (the mean across subjects) does not reveal how **each** individual came to behave the way that they do. It does **not** provide information relevant to understanding **the cause of individual differences**.

It is essential to point out that behavior analysis does **NOT** assert that every behavioral adaptation of every animal on earth is the result of nothing other than reinforcement (as it is sometimes incorrectly argued). Rather, because semipermanent adaption across the seconds to days time scale that occurs as the result of exposure to covariance in the environment accounts for a significant

portion of an individual's behavioral repertoire; it is therefore the prime candidate for the correct explanation for a significant portion of an individual's behavior.

The knowledge base of short time scale adaption in individuals is quite large and complex. It is covered as The Experimental Analysis of Behavior and is a full course.

e. Behavior Analysis is Practical and Practicable

As a direct result of the preceding four essential characteristics, Behavior Analysis is practical and practicable.

The career choice is between on the one hand: focusing on known and proven relationships that you have direct access to and can therefore do something about because you can prove that things are getting better or worse (behavior analysis); and on the other hand, focusing on presumed relationships between presumed entities over which you have little or no direct access, little or no ability to control and no way to prove that things are getting better or worse (traditional psychology).

Behavior analysis is practicable because it's skill set is teachable. It is not based on some indescribable intuition possessed by only special people. It is as teachable as medicine or engineering.

2. Additional Issues Pertaining to Understanding Behavior Analysis

a. The Point of Education in Behavior Analysis

The point of education in behavior analysis is to enable someone to: 1) see a pattern in behavior as the result of an understood fundamental process, and 2) be able to arrange the contingencies of reinforcement differently such that the desired behavior is highly likely. Simply being able to mindlessly repeat the steps used in some example that was used in some class is the antithesis of education. A student who sees mindlessly repeating words they memorized in class as their goal is spending their time and money on a fools' errand.

b. Conceptual Atrophy in Behavior Analysis Education

There is the potential for a significant weakness in the educational system which, ironically, stems from the success of a field. Typically, a field progresses from caring about and constantly dealing with basic issues, to focusing on higher level issues. For example, early practitioners of Behavior Analysis were keenly aware that the mentalism of traditional psychology made any advancement impossible because none of the questions were resolvable. The students of the pioneers of Behavior Analysis rarely got trapped by endless discussions resulting from mentalisms because those early practitioners of Behavior Analysis never permitted the empty challenges into serious discussion. Unfortunately, after the second generation, the arguments against mentalisms faded from memory. The prohibition against mentalisms became rote words because few experienced the frustration of endless unresolvable arguments. By the third generation, some

behavior analysts began discovering the "joys" of the appearance of explanation offered by mentalism without realizing the futility of these fundamentally empty explanations. For example, "the behavior changes when the cognitive process determines that the change is needed" (the futility being what causes the cognitive process to decide that?). Texts such as the present one review the arguments against mentalism so that its readers need not refight battles that have already been won. The dictum is certainly true that people who don't understand history are cursed to relive it.

c. Pernicious Irresponsibility in Behavior Analysis Education

Many students blow off the task of coming to see the actual dolphin used in this preface. While actually seeing the dolphin in the preface of this text is unnecessary for success in life or even in this class, the successful refusal to deal with that particular challenge does illustrate a very serious weakness in the American educational system that needs to be understood. A student could pass a course without learning some important things, could graduate, and could come to practice their profession without understanding or even caring about some of the essentials in their field. This flaw can result in them making very serious errors with serious consequences.

In the professional world, many problems absolutely positively must be solved or else dire irreversible consequences happen. It's not as if life can be taken over, the way a major can be changed or the bad consequence can be erased by averaging with a few good consequences. Regardless of how difficult it is, not doing whatever work is necessary to succeed in one's profession is not an option.

The task of this text is to help you understand the conceptual foundations of behavior analysis now. It may not be easy, but it will surely be easier and less costly than the alternative. But it can help you only if you expend the effort to "see the dolphin" in virtually every single paragraph in this text.

III. Regarding This Text

I believe that my task is to help you to actually understand the organizing principles underlying phenomena covered by Psychology and Behavior Analysis (i.e., **see** the dolphin) not to simply teach you to mouth words. Even though it would take me literally only a few seconds of lecture time to cover the statement: "reinforcement makes us who we are" and you would be able to write the phrase on a final exam with no further study (thus proving me a fantastic teacher and you a fantastic student?), neither of us would have accomplished anything meaningful. The task of science is not to gather blind adherents mouthing slogans, but rather to enable people to understand nature; which is to be able to predict, control, synthesize, and control it.

I've tried to provide you with examples of important issues in such a way that it's easy to care about the alternatives and easy to see which is the correct answer. From there, it's generally also easy to deal with complex cases. As a result, the style of the text is informal with many examples, analogies, and metaphors. The intent is to show you why it matters enough for you to take the extra effort to do it right; why doing it right is exactly what it is; and to be able to connect the words of the concepts to the functional relationships going on in the world around you. That is to say how you can avoid the errors made by basically good people whose only fault was not realizing what could go wrong with what they thought in their "hearts" was right.

Some parts of the text are intended to prompt your imagination or insure that you are able to see an issue from a particular point of view. Try to allow yourself to get into the examples. With any luck, it will make the text more enjoyable as well as more informative. I agree that some of the examples have obvious solutions or are simplistic, while the actual issues are subtle, complex, or in a gray area. But again, complex issues are best dealt with after understanding the basic issues.

Another license I have taken is to write the text for students rather than the most punctilious and learned, or sophistic people in the field. The intent is to begin a path toward a relatively recondite worldview.

Additionally, in an attempt to keep issues from being completely opaque to beginners, I started with familiar concepts such as "truth", "reality", and "knowledge", and clarified their definition to remove any erroneous connotation. There are two reasons for this approach. First, it is easier to identify and delete the erroneous aspects of an existing concept than to build a complex, full concept with its many divergent correct and incorrect aspects from scratch. Secondly, it avoids complex convoluted and unfamiliar ways of discussing issues that add to the difficulty of understanding them and therefore seeing the value of a behavior analytical paradigm. More strategically, it avoids the attempt to establish two separate vocabularies – one for the academic world and one for the everyday world. Vocabulary constantly enforced by a rigorous academic environment too easily decays into sloppy use when removed from the enforced contingencies. Sloppy use then, too easily decays to sloppy beliefs. Throughout your entire life and in all the contexts in which you will find yourself, you will have to be able to confidently separate the correct meaning of terms from their common but erroneous meanings and explain and defend why your usage of the words are more productive than theirs. You might as well start now. Even though there are great areas of overlap between the common meaning and the meaning in this text, the difference in meaning is essential to understand. The usage in the text is the correct usage. The common level usage if different is simply wrong. There are cautionary alerts throughout the text.

The underlying rationale for this style of presentation comes from the fact that, in order for many of us to build our personal wisdom, we often need conceptual or motivational scaffolding. Once our worldview is formed we can discard the scaffolding, but it is, nevertheless, important for the construction. It doesn't matter how you wish to communicate the concepts covered in this text once you understand them. The bottom line is that you must have an acceptable rationale

for what you believe, and, in turn, for what you do.

My writing style is my speaking style. When you read this text, try to hear it. It's not written to be read in a monotone. Additionally, the text is in a lecture notes style. See them as prompts for you to offer your view on the matter in class. This text is a work in progress. I accept that this text is not perfect. I revise it every year. I see things to fix every time I read it. However, to simplify your task of learning, see this text for what it can do for you, rather than for what it has not yet done. The bottom line is that it is critical for you to begin coming to grips with the general forms of the issues presented in this text. Regardless of whether you become a practitioner or a researcher, sooner or later your career will depend on how successfully you can cope with each problem. As we cover the material, consider alternatives to the positions expressed and the relative cost benefit ratios of the various approaches. What could be gained? What could go wrong? I believe that with these techniques you can learn for reasons other than the removal of pain, and that you can be motivated for reasons other than avoiding the repetition of a mistake you once made.

This course has evolved. When I first taught the course, I spent my time explaining what the author of the textbook must have meant. After a while, I found myself simply presenting and explaining the important issues and disregarding the text. About that time, I also discovered that I was too busy lecturing and students were too busy taking notes to think about what I had said and too busy to discuss the issues. This led me to hand out an outline of my lecture to save the students from spending all their time taking notes. Because I gave students copies of my lectures and the students could simply read the information for themselves, I felt compelled to develop new lectures on additional material so I would have original things to say in my lecture and not be just reading the book to my class. This only led to more note taking.

As a result of this vicious cycle, I have come to the conclusion that if it's important enough for you to know, then it's important enough for me to give to you in writing (i.e., this text) so that you can study it and do whatever you have to do to understand it. Said from the opposite perspective, this means that the lectures will rarely cover material not already in your preprinted material. My view is that it's senseless to hold back important information just so that students can be entertained by new material they haven't seen or heard before. Class time is when you should be asking questions, and considering the issues raised by other students, and interactively formulating your own position on these very important issues, rather than a time to be mindlessly writing as fast as you can with no time to understand what was said. Neither should you put off doing your homework and expect to passively listen to me read out loud what you should have poured over for yourself. Consider my very brief overview of the topics in class as nothing more than a vehicle with which to organize or time your questions and discussion, because that's how they are given.

Additionally, plan on reading the text completely through from beginning to end after the semester is over. Recall that you spent a lot of time and money to "see the dolphin." Don't stop at learning to write answers on a test. The text cannot discuss the big picture and the details necessary for you to fully understand

the big picture all at the same time. The important details of the big picture can be several chapters after the initial introduction of the big picture or vice versa. The second time through you can appreciate the big picture better because you know the fine details or you can better understand the details because you know the big picture. Knowledge works better if each idea is connected to every other node, rather than each idea only being connected to what went directly before or directly after in a single straight line, as it must be written. Just as a good symphony or a good pizza is the simultaneous blending of many elements, wisdom is a perspective gained by correctly understanding how many important ideas fit together.

If you have trouble with some sections, go to Wikipedia or Google or even other texts. Even though there may be substantial amounts of erroneous information out there on the web and in libraries, there will be something that explains an issue in just the right way for you to easily understand. At worst, you will be exposed to a variety of ways people have become confused and will know what not to do. If you find something that contradicts something in this text and it seems correct, bring it to class and present it. Either you will be corrected or the text will be corrected. It's a win-win situation.

1. Consider the headings the information to learn and the text as only an explanation of what the headings mean. Pay particular attention to the heading outline. The Table of Contents provides a well-structured and detailed summary of the important material in this text. Be sure to overview the Table of Contents before and after reading each chapter. Use the Table of Contents as a study guide. You should be able to reproduce its major components and annotate each line before proceeding to the next sections and chapters.

Research has shown that many people skip over headings. That is an extremely bad habit. When you come to a heading, read it three times if necessary, to force yourself to clearly understand what it means, then skim over of what you are about to read before reading the text.

To repeat, above all, pay very close attention to the headings. They tell you what is important and how those important issues are related. Do not allow yourself to skip a heading, ever! - you will miss how the information fits within a structure. Without the structure, you will have difficulty seeing and remembering the big picture. Additionally, you will tend to miss the point of the discussion following the heading. If you highlight anything, highlight the heading and while reading that section be thinking how it "validates" or clarifies the point of the heading.

2. You must totally understand every single figure and table. If you cannot reproduce the figure functionally correct, then your understanding of the material is deficient. It is rather like drawing a dolphin as a box when asked what the dolphin looked like. Do not pass on to a subsequent section until you can reproduce the figure and correctly specify why each element of the figure is included. Every test will have a figure for which you must state the point and provide all the labels.

3. What is Behavior Analysis today will be all of Psychology tomorrow. In the same way medicine matured and evolved from unprincipled folk wisdoms

that had only a marginal impact on a patient's quality of life, so too is psychology maturing and evolving from a weak ineffective foundation. "Psychology" as used in the present text refers to the fully modern, fully scientific study of the behavioral adaptation of individual organisms.

Behavior analysis is not the worship of words that came from Skinner, nor is it confined to what Skinner defined as operant reinforcement in 1938, nor is it fixing autistic children. Rather, behavior analysis is the rigorous understanding and practice of the intersection of science, and the semi-permanent short time scale adaptation of individual organisms, all of which are specified as external functional relationships. It is the leading edge of what that time scale of psychology is evolving into.

4. Learning the course material comes not from what the text gives you, but rather from what you think through for yourself. Try to always keep in mind the critical, but overlooked, problem in education is that learning has more in common with building muscles or learning to play the piano than with a glass of water being filled from a pitcher by a waiter. A second simple metaphor, familiar to everyone for the necessity to be an active learner, is the difference between being the driver and being a passenger on a road trip. The active driver can easily return to the destination again, while the passive passenger cannot. Learning is an activity that requires an active learner, rather than a passive recipient.

5. The class meetings will be interactive question and answer sessions rather than lectures. A block of information targeted to the class as a whole is better printed and handed out to the class (as it has been in this text). Each student can then work through the information at their own pace and identify any particular aspects that they have trouble understanding. The particular needs of individual students can then best be solved one on one in an interactive question and answer period. The incongruity of informing a group and teaching an individual is well illustrated by imagining trying to teach ten individuals to master their piano playing by lecturing to the class as a whole.

6. Ask whatever questions are necessary in class as many times as necessary until you understand and truly "see the dolphin." With some issues, you'll get the organizing principle right away, and will wonder why others are taking so long to get it, or require so many examples; other times your roles may be reversed. In either event, always keep in mind that your task is to understand for yourself the issues we cover, with anything less, we are all on a fool's errand. It is empty pedagogy for me to simply teach you to say words whenever you confront a problem. This text is intended to help you see the picture, not to just lay the facts before you and move on, leaving you to learn the hard way after you graduate.

7. As a student, always ask a question if you are unsure of something. Never hide what you don't know, it would be like hiding that pesky lump from your doctor. Students are expected to have questions. Employees, on the other hand, are expected to already know everything and are evaluated, paid, and promoted based on how knowledgeable they are. As a result, your obvious task as a student is to come to understand anything you don't now know before you start

your career, not to get through graduate school pulling one over on everyone. You are paying a lot of money and spending a lot of time to rid yourself of what you don't know. Enable your faculty to do the thing they enjoy the most: explaining things. Get your money's worth, and then some.

8. Do not confuse the referent that could be, or has been, applied to a term with the referent that should be applied to a term, and do not presume that everyone you encounter in the future will have the same referent, labels, or definitions as you do. Unfortunately, there are substantial differences in the terms different people use and what they mean by those terms. If it's important that the other people understand exactly what you mean, assure yourself that they do in fact understand all the meaning of your terms before building on them or presuming that you have communicated. Anything less would be the same as using English to talk to someone who does not speak English and who doesn't understand a word you say. Saying "behavior analysis discovers the truth" or "science produces truth" to someone you just met will more than likely simply communicate that you are a student repeating words that your professor said in some lecture and that it is very unlikely that you understood what you are talking about. When speaking, the task is to avoid sloppy psychobabble on the one hand, and pedantically burying your listeners in endless disclaimers on the other. When listening, the task is to avoid sophistically pointing out every conceivable special case that could invalidate the message on the one hand and passively accepting everything you are told on the other **The challenge is to maintain productive meaningful communication**.

IV. How You Can Gain Control of Your Studying So That You Can Have a Good Career

With only a little reflection, it should be obvious that, of all of your behaviors that you could change (what you eat, exercise, smoking, etc.) studying will have the most profound and long lasting effect. If you are studying less than you want, the solution is easy. Gain control of your studying behavior by the same psychological processes that govern all behavior.

A. Be Sure to Reinforce Studying

Be sure to reinforce your studying behavior after each time you have studied. Keep in mind that the task before you is to increase the rate of studying in the future, not to bribe (or prompt) your studying on a particular occasion. If you think your task is to bribe studying, then once you have already done the work, it's too easy to renege and not pay off because you already got what the bribe was for. Don't be a stingy miser with your reinforcers; it would hurt your behavior more than it would save your pocket. In point of fact, as you should already know, the sad result will be not enough studying in the future. With any luck, your program of behavior modification of study behavior will establish a habit you want, will make studying an intrinsic reinforcer, and will give you a career that you will enjoy and will pay well.

B. Build Up Your Studying Stamina

Start with small simple study tasks that you are absolutely guaranteed to finish, even if it is doing nothing more than simply opening the text. Then gradually build up your studying stamina from whatever it is now by reinforcing each increase. Don't demand the unattainable or you will not get any better. While many students could easily work a 45-hour week or train for a sport or musical skill 45 hours a week, they find going to class and studying 45 hours a week nearly impossible. It may help if you keep in mind that your position on the distribution of study (or sports or music) hours with respect to the class is going to be pretty close to your position on the distribution of career income with respect to the class.

Students are expected to work on academics 45 hours a week (lectures and homework). If you are not studying and focused exclusively on academics 45 hours a week, then you are not doing your share of the work to make you what you want to be. Only you can give yourself muscles, **only** you can give yourself knowledge.

C. Take Advantage of Stimulus Control

Always study in one place and never do anything else there. As a result, every time you sit in that chair, you will feel like studying rather than something else. Be sure to get up and move if someone comes in to visit, or you answer the phon

D. Increase Your Probability of Initiating Studying by Adding a Delay to Temptations

Often students say that time management failures are at the heart of their problems. Time management failures occur because an immediate reward is vastly stronger than a delayed reward, even if the immediate reward is tiny (like talking to a friend about a movie) and the delayed reward is enormous (like having a satisfying lifelong career). The best way to choose the larger later goal (studying and having a good career) is to avoid getting into situations where small immediate rewards can tempt you away from working toward your larger later goal. For example, turn off your phone and put your phone and computer far enough away from where you study, that you are not tempted to look at them.

Acknowledgment

It would be preposterous to suggest that anything in this text had no precursors or history and sprang into existence in its final form de novo from the pen of the author. This text heavily depends on the many scholars who originated the conceptualizations in this text, especially B. F. Skinner and Murray Sidman. We are all better because of the long line of scholars who together conceptualized behavior analysis, and we are in their debt.

I would also like to thank the many scholars, colleagues, and students who over many semesters have contributed one-on-one to making this text clearer and more comprehensive with each revision (as well as making this course a joy to teach). I would like to especially thank David Palmer, Max Hocutt, Terry Smith, John Donahoe, and John Malone, for their help in making this text authoritative. I do not suggest that everything in the text is consistent with everything they have said and I certainly accept responsibility for any deviations from their positions.

Chapter 1

The Relevance of Science to Psychology

I. Formalization of What You Accept as Your Goals / Obligations

A. Do what it takes to be ethical
   1. definition of ethical
      a. do unto others as you would have them do unto you
      b. do the greatest good for the greatest number
      c. objective interest before self-interest
      d. efficiently eliminate ignorance or relieve suffering
      e. deal with your limitations honestly
   2. review: your self-imposed goal or onus to do those things that will make you ethical

B. Do what it takes to be prosperous
   1. definition of prosperous
      a. good job
      b. security
      c. upward mobility
      d. job satisfaction
      e. provide for you and your family
      f. good quality of life
   2. review: your self-imposed goal or onus to do those things that will make you prosperous

II. Knowing What You're Doing is Necessary in Order to Be Ethical and Prosperous

A. Definition of knowing what you're doing
   1. separate reality from illusion
   2. solve problems faster and more effectively than most people
   3. function without supervision
   4. implement recondite information
   5. make consistent progress
   6. be truly effective
   7. use the best available knowledge

III. Understanding the Truth or Reality Gives You Your Best Bet to Know What You're Doing

A. Conceptual precursor: Venn diagrams
B. Conceptual preview: science and truth
C. Demand what is labeled truth or reality
    1. actual definition or meaning of truth or reality
        a. empirical
        b. reliable
        c. multiple converging evidence
        d. consistency with the paradigmatic framework labeled science
        e. consensually validated
        f. operationally / functionally defined
            i. the distinction between operational and functional definitions
            ii. operational definition
            iii. functional definition
            iv. conceptual follow-up: hybrid usage
        g. coda: truth and reality versus opinion and delusion
D. Have what is labeled understanding
    1. demonstrations of, or meaning of, understanding
        a. describe
        b. predict
        c. control
        d. synthesize
        e. explain
        f. coda: understanding versus opinion and delusion

IV. Science is the Label for the Activity That Gives You Your Best Bet to be That Which is Labeled Ethical and Prosperous

V. Conclusion

VI. Conceptual Follow-Up: Vocabulary Referents and Decisiveness of Arguments

A. Vocabulary referents
B. Decisiveness of arguments
C. Cautionary advisory
D. Coda

VII. Schematic Review of the Logic of the Proof Showing That Science is Your Best Bet to be Ethical and Prosperous

CHAPTER 1

The Relevance of Science to Psychology

Simply put, science gives you your best chance to be ethical and your best chance to be prosperous in the practice of your psychology. This chapter provides proof that that statement is a fact rather than an assertion, a hope, or a delusion. Said from a different perspective, this chapter provides an axiom based deductive proof that you must be scientific in your practice of psychology, anything less is unethical and is unlikely to earn you a good income. It is essential to understand that science is not a religion that you should ascribe to "simply because". Rather, if you want to be ethical and prosperous, then first you must be a scientific psychologist.

Presumably you want to be ethical and/or prosperous in your career in psychology. That means you will have to figure out what will make you ethical and/or prosperous. We will see that the answer to your quest is scientific psychology. Scientific psychology is what will give you your best chance to be ethical and prosperous in your career, but that will require that you find out what scientific psychology is, understand it, and practice it.

Unfortunately, the cost of practicing scientific psychology is that you will have to work harder than the people who are only polishing their appearance of being ethical, and you will have to work harder than the people who are satisfied by kidding themselves about the efficacy of their procedures. Both of those groups are delusional about their future career prospects.

If I were to ask you to list five good things about lynching someone, you would, after the shock of the apparent oxymoron wore off, put down that it's quick, inexpensive, requires no difficult or complex preparation, and that those who do it claim that it's appropriate, that they enjoy doing it because they're helping society, and that they can find plenty of friends that think just as they do. If I were to ask you to list 5 bad things about civil law, you would point out that it is slow, expensive, requires a lot of preparation and work, and is stressful because it must be done right and isn't always fun.

The challenge faced by someone interested in psychology is analogous to that faced by a judge. We can do to our readers and patients what feels intuitively satisfying and what does not require taking difficult courses (i.e., lynch them), or we can become properly prepared at whatever the cost to do what is objectively the best thing possible.

In criminal justice, no one argues that the easy path (lynching) is better than the hard path (civil law). We should be equally offended when someone in psychology wants to do things in some particular way simply because it is the easiest way to graduate and has the least homework.

The logic of this chapter addresses itself to the question: is there any reason

for you to do anything other than the easiest, fastest, simplest most natural thing that any 15-year old does off the top of their head in the practice of your profession? Is there any reason to know anything more than you already know or to behave any differently? Is there any reason to expend the extra effort to actually understand the difficult aspects of the practice of psychology rather than simply going around doing what your intuition tells you?

The following step-by-step explicit reasoning shows, in common level language, that science is relevant and even essential to psychologists involved in either the application of psychology (e.g., ABA behavior modification) or to the discovery of new behavioral principles (e.g., EAB research).

Follow the development of the logic for the fact that science is relevant for both researchers and practitioners in psychology by noting the steps on the figure at the end of this chapter as you read the text throughout the rest of this chapter. In that way, it will be relatively easy to follow the logic in terms of everyday terminology as well as in terms of the actual referents for those labels.

I. Formalization of What You Accept as Your Goals/Obligations

The first step in building a logical foundation for your practice of psychology is to decide what is at the heart of your system of wants, beliefs or values. An onus is the most primitive or most basic demand a person feels obliged to meet, even if it's not fun and even if it's not easy. Generally, these are obligations so basic as to require no justification. An example may be caring for your parents when they are feeble even if they have grown mean. In the present case, it is working hard to learn what is necessary for you to get what you want out of your career.

A. Do What it Takes to be Ethical

People often verbalize that they are willing to work as hard as is necessary to be ethical, even if it means voluntarily taking harder courses or spending more time doing homework. The following are examples of what professionals consider ethical.

1. Definition of Ethical

It may be that the only clear operational definition of what it is to be ethical is to enumerate instances of being ethical. The following set includes some of the typical things that people consider essential examples of being ethical.

a. Do Unto Others as You Would Have Them Do Unto You

You would want to go to a maximally competent "therapist" who understands what is really going on and how to fix your problem. You would want to read a maximally revealing paper that helps you understand the actual determinants of a process.

b. Do the Greatest Good for the Greatest Number

In complex situations where no simple completely right versus completely wrong decision can be made, a maximizing rule only makes sense. Any decision should be based on an understanding of the big picture rather than a first, narrow impression. What is the best answer for the larger perspective out of the possible alternatives? What will most positively affect the greatest number? What will have the least negative impact? The point of triage during medical emergencies is to provide the greatest good for the greatest number.

c. Objective Interest Before Self Interest

If you have to study more to understand a problem; work harder to get the job done; research more rather than publish sooner; or give up an erroneous position to which you are emotionally committed, then so be it. Decisions should be based on the facts rather than self-interest.

d. Efficiently Eliminate Ignorance or Relieve Suffering

If you are trying to establish appropriate behaviors in people, you must know how to help people and help them in the best possible way. If you are adding to the knowledge base of psychology by doing research, you must provide your reader with the most useful knowledge presented in the most articulate way possible. The best solution requires a clear understanding of the actual factors involved.

e. Deal With Your Limitations Honestly

You must know what you can or cannot do. Solve the problem when you can, but defer to others when appropriate. Terminate if you are not helping, even if it means a loss of income. Pass a research question on if you cannot handle it. Your decision must be based on your ability to understand the determinants of the task.

2. Review: Your Self-Imposed Goal or Onus to Do Those Things That Will Make You Ethical

The preceding list of skills, activities, and attitudes details what are generally labeled ethical behaviors. Being ethical is what gives behavior analysts the right to consider themselves better than money-grubbing self-serving con artists. A Psychologist who simply does what he "thinks" is right or "feels" is right or "knows" is right is really no better than a con man. Both usually hurt people,

produce half-truths, and are called quacks.

While precisely defining what is morally right and ethical such that all people will agree is very difficult; it is relatively easy to identify things that are unethical. As a minimum, it is morally wrong to do something other than what is maximally beneficial and maximally efficient to someone in your care. It is morally wrong to publish a paper that leaves an impression that is not supported by the facts. The ethical foundation of psychology therefore hinges on having the best available understanding of the nature of behavior, the best available understanding of the problem at hand, and the best available way to accomplish the solution. To the extent that we have maximized our understanding of what is truly going on, we have passed an essential level of being ethical. To the extent that we use second-rate information or have a second-rate understanding, then we are unethical regardless of the definition of being ethical. Interesting enough, you can be wrong and still be ethical, as long as your decision was based on the best available understanding at the time you made the decision.

Simply put, you cannot be ethical if you don't know what you're doing.

B. Do What it Takes to be Prosperous

People often verbalize that they are willing to work as hard as is necessary to be prosperous and have a good quality of life in the future, even if it means voluntarily taking harder courses or spending more time doing homework.

1. Definition of Prosperous

It is important to operationalize what it means to be prosperous. A good start is to list examples.

a. Good Job

Have a job that you enjoy doing.

b. Security

Have a job that allows you to keep it as long as you want it.

c. Upward Mobility

Have a job that provides you with more frequent promotions than average so that you can make steady progress toward obtaining your long time scale goals.

d. Job Satisfaction

Have a job that enables you to feel good about your accomplishments.

e. Provide for You and Your Family

Have a job that allows you to provide your family with security and material goods.

f. Good Quality of Life

Have a job that allows you to enjoy life and recreation outside the work place.

2. Review: Your Self-Imposed Goal or Onus to Do Those Things That Will Make You Prosperous

Psychologists have a right to expect to be prosperous in their profession. You have a right to expect a good job. However, it is not enough to only want to be a psychologist, you have to be good at it to succeed. Therefore, there are pragmatic reasons, as well as ethical reasons, for you to truly understand the nature of behavior, truly understand the problem, truly understand the best solution, and truly understand the best way to accomplish the solution. To the extent that we have maximized our understanding of what is truly going on, and truly understand the issue as well as anybody, we are likely to be successful. To the extent that we use second-rate information or have a second-rate understanding, then we are in jeopardy of being unsuccessful.

The referent for the common level phrase "knowing what you are doing" is the most likely thing that will help you in becoming successful in your profession. If you don't know what you're doing, you are at risk of not being very prosperous and will surely be unethical.

II. Knowing What You're Doing is Necessary in Order to Be Ethical and Prosperous

The previous section could pretty much be taken for granted because we all pretty much feel some onus to do what it takes to be ethical, and some onus to do what it takes to be prosperous, even if it's not the path of least resistance.

The second step in building a logical foundation for your practice of psychology is to determine just what will make you ethical and prosperous. Being ethical is not the same as doing what you think is right, and a good life is not something you are guaranteed by graduating. In point of fact, both require that you know what you are doing. The following is a series of skills that exemplify an operational definition of knowing what you're doing.

A. Definition of Knowing What You're Doing

1. Separate Reality from Illusion

All theories claim to be correct and all therapeutic procedures claim to be right. However, some therapies and theories are in fact wrong. Just as all parents consider their children good kids, all weight loss programs claim to work, and all used-car salesmen claim that their cars are good buys. Unfortunately, the immediate, naively perceived, real world can trick us like a magician tricks inexperienced children. If you are to become a good consumer of psychological knowledge you must be able to separate truth from fiction even when appearances are deceiving and all around you believe the illusion.

2. Solve Problems Faster and More Effectively Than Most People

A simple technician can cope with problems once they are trained to step through that particular solution. A professional on the other hand can solve problems that have never before occurred. This distinction was the essential element in the difference between the TV character House and his students. The difference between a bright high school graduate with 7 years of experience in the real world as a nurse and a person with a medical degree is the difference between vocational and professional education.

This is because professionals are specifically trained how to solve problems and find the real answers. The ability to discover the true determinants of behavior is an essential prerequisite of being a professional.

In general, a professional must have the analytical skills necessary to unravel complex behaviors into understood functional relationships, and the competency to design procedures which will clarify causal factors or alter behavior. The tasks you must solve will quickly exceed the knowledge you have been given. Psychology has come an unimaginably long way since 1990 (about where history of psychology books leave off) and a very long way since the 2010s when most current faculty graduated.

Gauss, a brilliant mathematician, provides an exemplar of problem solving. He was required to add all the numbers from 1 to 1000 as punishment for some transgression in grade school. He completed his punishment in just a few minutes because he was able to realize that starting at the beginning of the list and taking consecutive numbers would make the next number get bigger by one while taking numbers starting from the end of the list would make the next numbers get smaller by one. In fact, the sum of the first and last number of a series would be the same as the second number and the second from the last number, etc., each pair would sum to one more than the number of numbers; and the number of those pairs would be half the numbers in the list. The sum would therefore be $(n+1) * (n/2)$. (It is a revealing commentary on what can pass for education when, because he finished in just a few minutes, the teacher punished him a second time, this time for cheating at his punishment!)

3. Function Without Supervision

The best jobs go to those who can function without supervision. Workers who only can do what they are told while being watched and told how to do every step are a dime a dozen.

4. Implement Recondite Information

Obviously, the knowledge base of humans has surpassed what is explainable to a 5-year old. In fact, it has surpassed what is quickly explainable to many college graduates. You must be able to understand the advanced and sophisticated knowledge of psychology in order to properly function as a psychologist.

5. Make Consistent Progress

If you are to succeed at what you are doing you must be right more often than you are wrong. You must make consistent progress. If you are to make consistent progress, then you must know when things are getting better and when they are getting worse. In fact, a theorem in mathematics shows that unsystematic (random) movements get nowhere. A drunk walking from a lamppost and turning randomly will not stray far from the lamppost. This principle is applicable to both the field of Psychology as a whole and you as an individual researcher or therapist.

Consistent progress requires the ability to separate correct from incorrect feedback. With accurate feedback, errors can be eliminated and correct solutions obtained. Imagine getting your clues in the game "hotter and colder" from a computer which is randomly saying hotter and colder, or from someone who doesn't know where to steer you. You would stumble around, always thinking you were on the right track but in reality, you would be lost, never getting any closer to the solution. Similarly, common sense is useless in Psychology; it moves you back and forth in no consistent direction. For every adage that points you one way, there is another one that moves you the other way (e.g., it's never too late - you can't teach an old dog new tricks / he who hesitates is lost - look before you leap).

6. Be Truly Effective

You will be required to demonstrate the efficacy of what you do when the people supplying your income become good consumers. Additionally, to be ethical, you must be effective.

Agencies that fund psychological services or research expect to get something for their money. This is increasingly so as government agencies become more accountable for their expenditures. You will be required to show that you produced something worth more than the money spent.

The courts are increasingly involved in psychological services. Malpractice suits are now a part of professional psychology. It is likely that you will be required to present evidence admissible in a court of law, and under cross examination by a well-informed lawyer which proves beyond a shadow of doubt that your

procedures work. It's one thing to believe something in a classroom just because you like it; it's something else to announce in a court of law that you gave someone a lobotomy just because you like some particular theory. You better be able to prove it when your opposing lawyer is smart enough not to be fooled by rhetoric that sounds impressive, but is fallacious.

The outcome of a malpractice suit against you is governed by the quality of your knowledge. A good threshold for acceptable reasons for accepting a position as true can be had with a simple thought experiment. For example, what would you consider acceptable if you were a juror on a malpractice case brought against a friend of yours? What would it take to make you side against your friend? Whatever degree of proof of validity that is, is the degree of proof you should require of any procedure you are considering using on your patients. Your patients have the right to the same quality of proof that you demand.

The hallmark of free enterprise is that the best is likely to prosper and the ineffective are likely to disappear. Natural contingencies simply work that way. Producing results is a function of your understanding of the true determinants of behavior.

You will be able to attract more grants or customers if you can show that your procedures actually work rather than simply trying to talk your readers or customers into believing you had accomplished something. Your status with respect to other job candidates and fellow workers will most likely be based on your competence and ability to produce results. Your research papers will have a greater impact if you irrefutably demonstrate important relationships. You will be more likely to be upwardly mobile if your procedures work better than your colleague's procedures.

Sooner or later you will be held accountable for what you do. Performance evaluations are becoming a fact of life. Your only security will be to have done what has the best possible evidence supporting it, proven in the most objective way possible. Layoffs never start with the most competent and productive workers. Grants are always funded in order of their competence.

7. Use the Best Available Knowledge

It will be necessary to constantly update your knowledge base as new knowledge is discovered and proven. Imagine going to a physician for help and that the physician was still using treatments popular when he graduated 30 years ago because he thought studying is something you have to do only when a student. The idea that you will be able to study for a few years and then coast for the rest of your life is foolish beyond measure. You would not go to a physician, car mechanic, clothing designer, or anyone else that thought that way. It is silly to believe the TV character Dr. House would be the greatest diagnostician on earth and not be almost completely consumed by constantly reading the current research.

III. Understanding the Truth or Reality Gives You Your Best Bet to Know What You're Doing

The third step in lifting our onus is to determine the actual essential elements underlying all the skills or abilities that are commonly labeled "knowing what you're doing." In everyday language, knowing what you're doing is thought to be the result of understanding the truth. Therefore, the elements resulting in knowing what you're doing can be grouped into two rough classes (i.e., truth and understanding).

A. Conceptual Precursor: Venn Diagrams

Throughout the text, Venn diagrams are used to depict sets of elements and their relationship. For example, Figure 1.1.

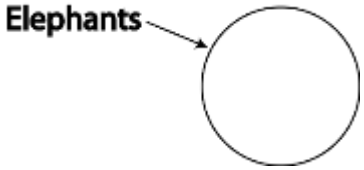

Figure 1.1 The circle represents the set of all elephants.

would represent the set "elephants." Figure 1.2 would represent the sets "elephants" and "females" and would show that some elephants are female but there could also be elephants that were not female and could be other things that are females but not elephants.

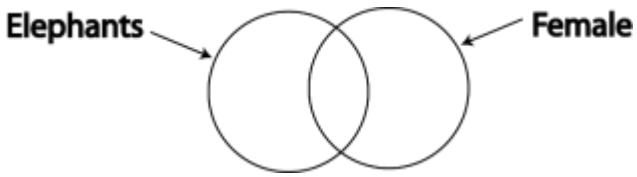

Figure 1.2 The left circle represents the set of all elephants. The right circle represents the set of all females. The overlap represents those elephants that are female or those females that are elephants. The segment of the elephant circle that does not overlap the female circle represents elephants that are not female. The convention in Venn diagrams is that the relative size of each portion of the figure does not indicate the relative proportion nor even that any elements are in that portion.

Unless explicitly stated, the actual physical proportion of overlap between the circles is not to be taken as the proportion of overlap in the sets. Any particular segment may contain all of the elements or none because the diagram is to represent possible or potential relationships not their proportions. For example, half of elephants are female even though the overlap between the circles is not half. Secondly, there are millions of times more females than elephants and the

percent of females that are elephants is infinitesimally small in comparison to all the female animals in existence.

B. Conceptual Preview: Science and Truth

While your current belief of what truth and understanding mean is basically correct, and your current evaluation of those concepts, i.e., that they are good things to have, is correct; there are likely to be several areas requiring reassessment. This entire text can be said to be a preliminary definition of the meaning of the terms truth and understanding. There are many similarities between your present notions and the philosophical ideal of truth and understanding, which is why the terms are used in this text but there are also many differences. The terms serve as excellent scaffolding to allow a beginning psychologist to develop the ability to sort out the events and complex concepts that are required of them. **However**, the terms also carry undesirable baggage and for that reason they are not typically used in professional discourse. You absolutely must not confuse your preconceived or common usage meaning of these terms with the definition developed in the text, and **never presume** that all people mean or hear the same thing when you say "truth" or "understanding".

In overview:

Actual science produces what in the final analysis is considered understanding actual truth as is illustrated in Figure 1.3.

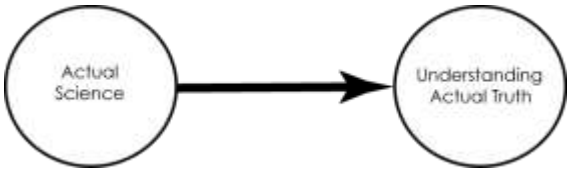

Figure 1.3 Actual science produces understanding actual truth.

It is not the case that any activity that anyone has ever labeled science produces the set of things that include everything anyone has ever labeled understanding truth.

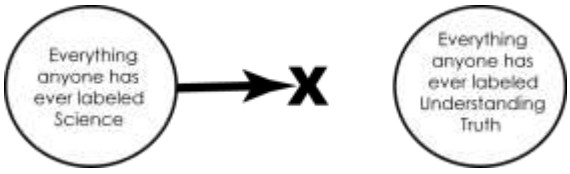

Figure 1.4 Everything anyone has ever labeled science does not produce everything anyone has ever labeled understanding truth.

Neither is it the case that actual science produces everything anyone has ever labeled understanding truth,

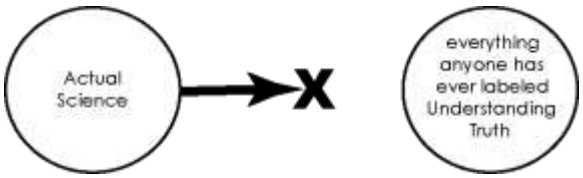

Figure 1.5 Actual science does not produce everything anyone has ever labeled understanding truth.

nor that understanding actual truth comes from everything anyone has ever labeled science.

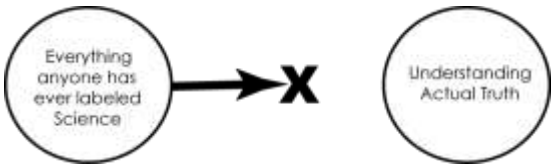

Figure 1.6 Everything anyone has ever labeled science does not necessarily produce understanding actual truth.

But, it is the case that that which actual science reveals **defines** understanding actual truth, and it is the case that understanding truth can have no further meaning, as is illustrated in Figure 1.7.

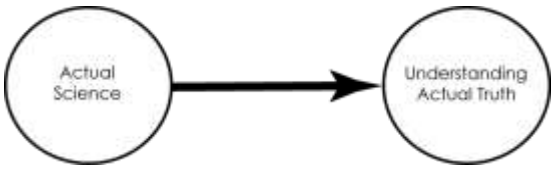

Figure 1.7 Actual science produces understanding actual truth.

Actual science is a subset of all those things that have ever been labeled science and understanding actual truth is a subset of all those things that have ever been labeled understanding truth.

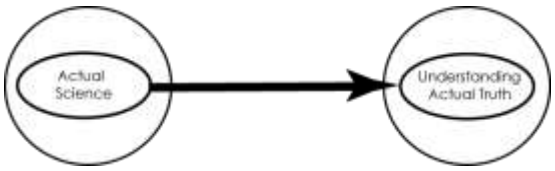

Figure 1.8 Actual science is a subset of everything anyone has ever labeled science, and understanding actual truth is a subset of everything anyone has ever labeled understanding truth.

Treatments based on understanding reality or understanding the actual truth are the ones that will most reliably work if anything can work. It should be self-evident that to the degree that you use procedures that don't work, you will be less likely to be ethical and prosperous. Alternatively, research that reveals the actual truth or reality will be the research most likely to have the greatest impact.

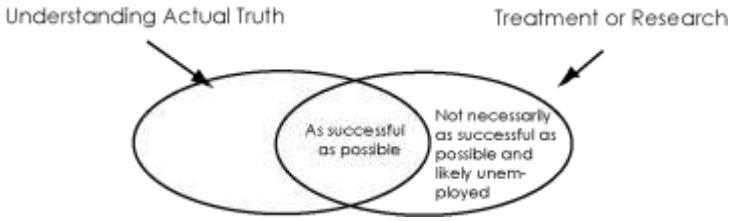

Figure 1.9 The intersection of understanding actual truth and a treatment or research procedure (i.e., a procedure based on understanding the actual truth) is, in the long run, as successful as is possible.

Finally, ethical behavior requires that you base all your treatments or research on understanding reality or understanding the actual truth. It should also be self-evident that to the degree that you do things that are not based on understanding reality or the actual truth, you are not ethical.

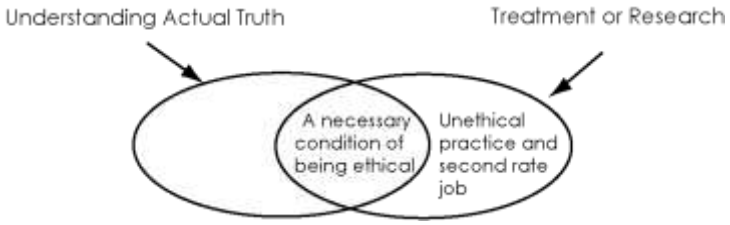

Figure 1.10 Anything other than the intersection of understanding actual truth and treatment or research procedure is unethical. It is possible for a scientifically valid procedure to be unethical but it's not possible for an unscientific procedure to be ethical.

After you graduate, what you label the sets that are labeled truth and understanding in this text is irrelevant. Besides simply knowing some concept names is unimportant; what is important is your understanding of the boundary of those concepts: what is included and excluded, and the rationale for their inclusion and exclusion, and why those elements are crucial to the practice of Psychology. It is unlikely that you will communicate to anyone simply by invoking those terms (or any others). People that do not understand science and the only meaning truth can actually have will need many many hours of discussion before they don't misunderstand what you mean when you talk to them about science or truth. People who pretty much understand science but have a slightly different view than yours will not be convinced one way or the other by shibboleths. They will want to understand the boundaries of your functional processes and see how well they solve problems. Sometimes authors taking the approach used in this text with respect to the terms truth and understanding say that the truth generated by science is spelled with a small "t" rather than a capital "T." The basic aspects of truth and understanding are detailed in the remainder of this chapter. The complexities of those issues are clarified in the remainder of the text.

C. Demand What is Labeled Truth or Reality

You must have good evidence that things are true before you believe in them

and that is not as simple as it sounds.

1) Unfortunately, truth is not necessarily obvious, what you like, nor the easiest.

2) Neither is common sense an acceptable arbiter of reality. Common sense can be as dangerous as helpful. Common sense is the intellectual force underlying adages, horoscopes, and the burning of witches. Common sense can only be misconstrued into some caricature of the truth in retrospect. Adages are true only in the sense that they predict everything, for example "opportunity knocks once," and "it's never too late." One or the other is certainly true on any one occasion. The need is to know in advance, not after the fact when it is too late.

3) That your mother, teacher, or best friend believes something or supports your view does not make it true either. Everyone, including a psychopathic murderer, has a mother, a best friend, and a dog that believes in them.

4) The fact that something is popularly known is also no reason to believe in it. There are groups of people who believe the earth is flat and that life forms don't evolve.

5) Feeling that you're right is of no help. Even though most people do believe that they can be wrong, few people ever believe that they are wrong this time. Most people can be talked into believing a nonsensical theory, and most people fall for personality tests that have nothing more than face validity.

It is necessary for you to accept that your blind faith in the validity of your "inner ability" to understand people and "recognize the truth" could be the problem rather than the solution. Your task is to set up a judicial system that will correctly judge the truth or falsity of issues independently of your gut feeling. The solution to this difficult challenge is to determine what in the past has been shown to produce correct solutions as opposed to procedures which only produced strong emotional commitment but little in the way of enduring truth.

Admittedly, it's easier and more fun to do things by your heart and intuition than by your head. For example, people are convinced that they are right while they're lynching someone. They also feel that a court hearing is an unnecessary delay and hardship that gets in the way. Lynchings require no homework and have no prerequisite and are therefore popular among people who care more about how they feel about something than understanding the truth.

In sum, we must be more concerned about truly understanding real facts rather than what we feel is the truth. We as psychologists have a great deal of power over people's lives. However, we cannot give ourselves the right to lynch our patients or readers just because they trust in us, they are unlikely to complain, and we earn a good living at it.

1. Actual Definition or Meaning of Truth or Reality

There must be rules to screen-out gut feelings that-you're-right, opinion, bias and conjecture from the truth. What makes something true? In simple terms, truth is an accurate description of something that is real. If three people tell you three different combinations to a safe, the one that works is the truth. It means that the information has passed a reality test. You already test perceptual

information. You would reality test. If you didn't test to confirm that things were real, you would be what is meant by crazy. You must learn to test verbal and abstract information in the same way - for the same reason. The importance of getting to the truth is obvious if you imagine a courtroom where all things were accepted as evidence and you were on trial, and the prosecutor hated your family and your ethnic origins. You could be lynched by the system. If the judge and jury did not test the reality of the information, you would have the same fate as a patient of an unscientific psychotherapist or the reader of an unscientific researcher.

The problem is that truth is not always obvious. The fact is, without deliberate and careful thinking we can easily slip into being no more intrinsically objective or intelligent than people we ridicule for their bias or stupidity. The good news is that contrary to some popular misconceptions, the discipline of psychology has more to offer than rhetorical self-serving tricks to convince people we really helped them, or that any problems, which resulted, were not actually caused by the therapy.

The following principles have been very useful in separating truth from fiction. Each is presented in its most straightforward version. The rest of this text could be seen as a clarification of the more subtle or complex versions of these definitions. Metaphorically, these definitions will have some scaffolding removed across the rest of the text but for now they are within reason.

a. Empirical

Empirical things are those things that can be detected with the senses directly such as a rock on a table, or indirectly through some instruments such as a microscope, a voltmeter, or a Geiger counter. Sense data is a primary arbiter of reality. Things are real because we can experience them not because we can imagine them or because we like them. We cannot claim that an alien being caused some event and then when no alien is found, claim that it must therefore be an invisible alien that only we can see or that we must infer. We cannot claim that an overactive ego caused the problem and then claim that it is detectable only by properly trained psychotherapists, of whom we are one and the questioners are not. If we have a theory that predicts something, but the empirical evidence is something different, we cannot then simply claim that there is something invisible that is changing everything and that the change is exactly what it would take for our theory to still be true (e.g., dark matter). Physics lost is right to claim it is a science when it made up dark matter to excuse the error in is predictions. If we wish to claim that something reasonable people cannot experience is real, then the burden is on us to prove it to a skeptical audience; that is only fair. That we can prove it to ourselves, our friends, and our students is taken for granted.

The demand for empiricism is not a demand for definitions to be simplistic. This is especially the case in psychology. The definition of a reflex is a case in point. A reflex is not the concrete pieces of meat between a stimulus and a response but rather the objectively observable reliable relationship between the concrete stimulus and the virtually inevitable concrete response (a functional

relationship). Similarly, memory is neither a presumed concrete chemical change in the brain nor activity in some non-empirical cognitive processing center, rather it is the objectively observable concrete relationship between a concrete input to an organism and a concrete delay and then a concrete response from the organism based on the original input (a functional relationship).

A common but erroneous inference based on typical memory experiment procedures has created confusion. For example, if an experimenter says "hippopotamus playing a piano" and the subject says nothing, then two days later the experimenter asks: "what did I say two days ago?" Then if the subject answers "hippopotamus playing a piano," it is sometimes wrongly argued that that series of events proves that the subject learned something without any evidence of that learning and, as a result, an experimenter can presume that learning has taken place before the empirical evidence in other cases. However, it takes only a little thought to imagine examples where when the subsequent empirical playback is requested the subject could not repeat the original material. That failure demonstrates that it is necessary to empirically prove that learning occurred in the original situation if you want to limit yourself or your discipline to only what is provable. After all, we have all failed a test asking us to recall the content of a lecture at least once in our educational career.

b. Reliable

Things are real or true if a second look confirms their existence. This is sometimes labeled test-retest reliability. If we add a column of numbers twice, and get the same answer; then the answer is likely to be correct. Reliability and how to maximize it is treated in much greater detail in Chapter 11.

c. Multiple Converging Evidence

The more evidence from the wider variety of sources, the more believable it is. If the police find a footprint the same size as yours at a murder scene, maybe it means you are guilty of murder, maybe it doesn't. However, if the police also find your wallet there, and the murder weapon in your house, and the tire tracks of your car at the murder scene, and the victim's jewelry at your house, and your teeth marks on the victim's throat, and a DVD of the murder with you in the starring role - well, then you're in trouble.

Unfortunately, the analogy is flawed because science and criminal justice play by different rules. In civil law, the outcome can be biased by a very good lawyer or a crooked judge. There is generally only one historical event, one trial, and one outcome in a civil proceeding and the results depend on which lawyer is smarter at forcing the perspective to be biased in their favor. A scientific principle on the other hand is a repeatable (reliable) empirical relationship which is demonstrated by many researchers (consensual validation) with many procedures in many situations (multiple converging evidence.)

In science, multiple converging evidence has two aspects: 1) multiple measures of different types and in different situations all indicating the same fact, and 2) a

principled explanatory context as detailed below which is very general with many cross-validating findings in the theoretical network which support the finding.

d. Consistency with the Paradigmatic Framework Labeled Science

Paradigms will be discussed in the next chapter, but to summarize: an event must be consistent with a wide variety of well-established principles in the explanatory context. This principle is related to multiple converging evidence, but specifically relates to the commonality or plausibility with the network of processes as accepted as the givens in that activity's frame of reference. For example, a "disappearing" coin in the hand of a magician is seen as a slight of hand trick by the scientific paradigm because matter going out of existence is not supported by any scientific principle anywhere. There is no precedent for such a thing even though you can "see" it "disappear" with your own eyes. If you see something that is inconsistent with everything understood by the paradigm, then you must look again.

e. Consensually Validated

If several observers who abide by the rules of science all agree concerning an event, then it is probably true. It is reliable; it is objective. This is sometimes labeled interobserver agreement. If only one person observes something and others do not observe the same thing, then it is subjective. Just as you believe that the true sum of a column of numbers is the one that both you and others have obtained, so does science depend on consensual support. This criterion avoids the problem of considering a dream or a drug induced hallucination a fact. For this reason, it is an essential criterion of science. If an explanation or theory precludes consensually validatable statements, then it is metaphysics not science. This criterion works especially well if the observers are widely separated with respect to theoretical orientation, time, etc.

Oddly enough, complete agreement is not necessary. You only need to agree over the issues under discussion and to whatever extent is necessary for the discussion to proceed. For example, if you want to know if your group can pay for the dinner at a restaurant you need not argue over whether you have $105.75 or $107.21 between you when the bill is only $25.00 It is an entirely different question however if the bill is $106.00.

Alternatively, as illustrated in Figure 1.11, if one person has a permissible range of acceptable topics to consider that is very broad such as both a truck bearing down on someone sitting in the road and ghosts (the outer circle) then a more empirically-minded person with a range of acceptable topics characterized by the medium-sized circle could agree to discuss the truck but refuse to be drawn into discussion of a ghost (one of the small circles).

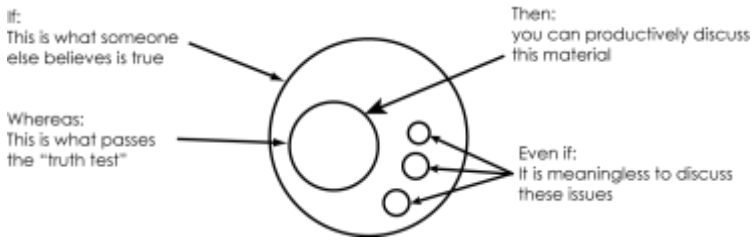

Figure 1.11 It can be productive to discuss material which passes the "truth test" with someone who also accepts those elements as true, even if one or the other person also believes things which cannot be proven.

f. Operationally/Functionally Defined

The conduct of science is a social activity. Consensual validation requires that multiple people communicate. If we are to validly communicate to others, we all must be able to correctly point to the same thing for which we are trying to obtain consensual validation.

A simple, albeit expensive example of the importance of common definitions could be had by asking someone from the Black Sea area to buy you a plane ticket to Georgia. A second example illustrating the problem of ambiguous definitions in Psychology can be built based on the typically vague meaning of intelligence.

As a case in point, imagine if you took an IQ test and scored IQ = 100 and the psychometrician said that based on the total picture obtained through clinical insight, your IQ was actually 150 you would, of course, admire their depth of knowledge. But, on the other hand, if you took an IQ test and scored IQ = 150, and the psychometrician said that in the final analysis you actually have an IQ of only 100. You would immediately ask what the mystery component was and how it was measured. You would demand that that clinical judgment be explicitly part of the definition of IQ and applicable to everyone. In the latter case, you would point out that it is wrong to believe intelligence is something indefinable or subjective and more than what an IQ test measures, and you would be right.

One way to characterize science is as a language community that emphasizes clarity and precision in its specifications of the boundary of its words through operationally/functionally defined terms.

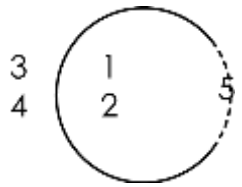

Figure 1.12 Set notation which illustrates the importance of clear boundaries. Numbers 1 and 2 correctly belong in the set. Numbers 3 and 4 are correctly placed outside the set. It is not currently known whether Number 5 should be placed inside or outside the set.

The meaning of a word is intended to include some elements and exclude others. In the case illustrated in Figure 1.12, elements 1 and 2 are correctly

included as part of the referent. Elements 3 and 4 are correctly excluded as not part of the referent. One of the tasks of science is to assign new elements such as 5 as either within or outside the meaning of the original term through empirical and reliable procedures with multiple converging evidence, consistency with the paradigmatic framework, consensual validation, and agreed to definitions.

The goal of science is to establish a clear boundary for its terms that includes every positive case and excludes every negative case. Operational/functional definitions enable researchers to productively evaluate whether a set correctly differentiates positive from negative cases by unambiguously providing the criteria with which to separate the elements. A good definition or concept (or theory) maps correctly onto nature and results in no discrepancies of correspondence.

i. The Distinction Between Operational and Functional Definitions

Common usage tends to conflate operational and functional definitions. When the issue is how does one type of definition differ from the other, operational definitions tend to be focused on measures of a thing's existence, while functional definitions are focused on what something does as a function of the occurrence of something else. It's not clear that the two terms have a universally agreed to usage such that there is no possible overlap. It's also not clear that such a dichotomy is necessary. The following two sections should be seen as a general rule of thumb separation of the two terms.

ii. Operational Definition

An operational definition is one way that reasonable people can assure themselves that they are talking about the same thing. This type of definition specifies what something "is." The operations used to produce, measure, or to prove something exists can be used to define the thing. For example, if you do this operation, then this operation, then this operation, what you get is an xxx (e.g., if you take a slice of bread and spread peanut butter on it, then add another piece of bread, then you have a peanut butter sandwich). A behavior analytic definition of hunger motivation used in animal learning research is the specification of the animal's percent of ad lib weight.

A divergent illustration of the importance of operationalization is given by Magna Carta and the Constitution of the United States. These documents were the operationalization of the power of government and people. They provided people with operationally defined rules, which in turn gave people "freedom." Both the government and the people were bound by the rules; neither could make things up to suit themselves. If the society agreed that a behavior was a crime, then the punishment was set to fit the crime as a matter of public record not as the whim of a single unaccountable individual. Behaviors that were not crimes could not become crimes on a whim.

iii. Functional Definition

Alternatively, a functional definition could be used to even more productively capture the nature of a thing. This type of definition specifies how something works. A functional definition is the set of functional relationships pertaining to a thing. The more complete the set, the more complete the definition. For example, if you do this to it you will get xx and if you do … and so on and so on. For example, the functional definition of a smart phone is the enumeration of all the things it will do and how to make it do them plus all the ways someone could use it. A complete functional definition is the result of a complete functional analysis.

A divergent example of a functional definition is establishing the meaning of a word in a foreign or ancient language by noting all the ways that word is used in that language.

Note that the term functional definition has also been used to refer to the evolutionary function that a behavior serves. That latter meaning is not used in the present text.

iv. Conceptual Follow-up: Hybrid Usage

Sometimes it is difficult to categorize a definition as clearly operational or clearly functional. A good example of a usage that is difficult to label is when a behavior is specified in terms of its objectively specifiable impact, consequence, or end such as all behaviors that result in the opening of a door. This latter way of specifying all the behaviors to be included in a class has also been labeled a teleonomic definition. A clearer but more cumbersome term would be "definition of-set-inclusion by common consequence." In that case, the common consequence could be considered the function of the behavior. In that regard, the definition could be labeled a functional definition. Alternatively, in that the behavior is defined in terms of the operations used to measure it, it could be labeled an operational definition.

g. Coda: Truth and Reality; Versus Opinion and Delusion

There are things which have the characteristics specified in the previous sections (empirical, reliable, etc.). We call these things true in everyday language. We also call these things scientifically established facts or reality. From that perspective, it can be seen that truth is nothing more than a scientific fact, and a scientific fact is nothing other than what we mean (or at least should mean) by the term truth.

Rather than to start with the notion of truth and then provide science as a subset of truth, this text starts with the notion of empirical, reliable evidence with multiple converging evidence, consistency with its paradigmatic framework which is operationally/functionally defined and has consensual validation, and questions the existence and meaningfulness of anything that is beyond. Figure 1.13 illustrates an essential aspect of the correct meaning of the word truth and the usage of the term in this text.

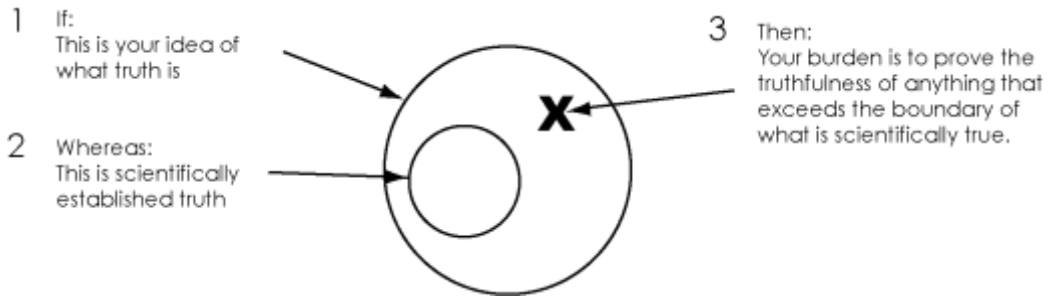

Figure 1.13 A Venn diagram illustrating that If X is not in the set of scientifically established truth, but X is in the set that someone believes to be true, then the burden is on them to prove that X is true.

If someone wants to offer something as a truth that is beyond what is established by science, then that person must in some way prove that notion is true, just as science had to have evidence for its assertions. The truthfulness of the new item must be proven in a way consistent with what people mean by truth. Even the common usage of truth does not mean anything anybody wants it to mean. As a result, if someone wants to extend the meaning of truth to something beyond what science has already substantiated, they must convince us that their new item is true. The irony is that by the rules embedded in the everyday meaning of the word truth, we would simply expand the number of scientifically established elements, not increase the difference between science and truth because the way to prove something is true is to show that it is empirical, reliable, has multiple converging evidence, is consensually validated, and is operationally/functionally defined.

It is important to note that we cannot simply assert that some position may eventually be true and therefore give it some special status. In the first place we cannot know the future. Secondly, that view would suggest that we no longer have to worry about the accuracy of what we do today. It could be argued that anything that can be conceived could also be conceived to be true or false. Sometime in the future, time could run backwards, or pigs could fly, etc. The allure of reifying a future truth that is beyond what we know today is that it seems to give the speaker the right or authority to believe anything they want. By simply asserting "this may be right eventually," that view seems to come to have a footing equal to any currently proven view. By similar logic, any finding could be rejected regardless of the evidence supporting it by simply asserting that sometimes, scientific positions change. These self-serving nihilistic tricks are impediments to progress. Truth resides in the present; all else is idle speculation. The best cure for this type of sophistic chicanery is to tell the pedant that they are guilty of murder because in the future they might be convicted of murder and you want to hang them now.

Having first stated the prior issues concerning truth, it is important to note that truth and reality actually do change and what is true today may not be true tomorrow. There is a coherent productive way to deal with this apparent oxymoron. This process, which underlies the dynamic nature of truth within science, is relatively recondite and is detailed in the next chapter.

D. Have What is Labeled Understanding

To understand is substantially more complex than simply saying that there is a rock on the table when there is a rock on the table, and saying there is no rock on the table when there is not a rock on the table. It is knowing how things are related and how they function. It is the ability to say "if this works on this thing, then that will work on that thing." It is the ability to generalize a relationship to a new thing or a new situation, and to know when those functional relationships will not generalize. To understand is to be able to form sets and correctly include the relevant and exclude the irrelevant even when those things have never been experienced before. It is to understand how things are related, and how things function. To understand is to have the ability to make reasonably accurate inferences about new things. To understand is to be under the control of the relevant stimuli contained in a situation and its functional relationships. To understand is to be able to adjust your behavior to suit a given situation. To understand is to know how to get from "theory" to the "real" world. All of these capacities can be categorized as the abilities to describe, predict, control, synthesize, and explain. It is as essential to science as separating facts from illusion.

The general idea of understanding can be illustrated by returning to the see the dolphin metaphor. For example, suppose a person came to be able to see the image embedded in the SIRDS picture; then that person would be able to describe aspects of the picture that no one has ever described before, as well as being unlikely to erroneously claim that a SIRDS had some image that it did not have. On the other hand, a person only memorizing that a particular SIRDS contained a dolphin without actually seeing the dolphin would be unlikely to identify novel aspects of the original image. That person would also be more likely to assert that images that were not in the SIRDS were in it because to them there was the same support for them as, to them, there had been for the dolphin. Understanding nature is essential.

We must understand how, when, and why things work the way they do. More analytically stated, you must be under the control of the relevant stimuli how they are related and the relevant rules of generality. You will be unable to predict what will happen in other situations and you will be unable to control behavior in alternate situations if you do not understand what makes behavior work the way it does and how classes of behavior are related.

The classic statement of someone who does not understand a process and its rules of generality is "it works in theory, but not in the real world." This means that that person can re-describe a classroom demonstration they once saw (e.g., there is a dolphin in the picture). But obviously never understood anything. An admittedly extreme example would be that after learning to give a pigeon bird seed to reinforce a desired behavior, they would give Johnny bird seed after doing math homework and would be surprised that the rate of homework did not increase. Their memorized words don't apply to Johnny and homework because the details of the solutions are different than the one they memorized in graduate school. The problem is that they never understood the principle underlying why the original phenomenon happened and what makes other behavior happen or not

happen in other situations. (Metaphorically, they never actually saw the dolphin in the picture; they only knew to repeat words.) As a second example, if a leaf is dropped on a windy day, the proper phrase is not "gravity works in theory but not in the real world," but rather, "gravity works on both leaves and on air; additionally, air currents affect the flight characteristics of leaves...."

Being able to do nothing more than follow directions, or memorize an answer to a specific case (i.e., to not understand) is well illustrated by the fable of the child sent shopping. Being sent to get butter he carried it home in his hand, a reasonable thing if you don't understand the properties of butter and hot summer days. It melted. His Auntie chastised him telling him he should have wrapped it in wet leaves. She then sent him to fetch a loaf of bread. He wrapped it in wet leaves. The story goes on for many trips: the boy always doing what he learned by rote, never understanding the principles underlying why he should do what he should do. As a result, he always did a right thing, not the right thing because what he did was in the wrong specific situation. He did not understand how things were related and why, and therefore he could not adjust his behavior to suit the situation.

To understand is also to be able to arrive at solutions for problems even if no one before has ever encountered those problems and for which neither a study guide nor answer sheet is available. If you understand a phenomenon you can use that information in new situations. Understanding begins with having a hunch, a rule, or a theory that specifies why things are happening the way they are and which specifies how the rules are to be modified so that they work in changed situations. Understanding provides you with the ability to be fruitful or productive because you can predict.

An additional problem with our hapless memorizer is that it is also very likely that over time their memory slowly shifted to something completely different from the original underlying machinery. For example, if you memorize nonsense syllables or disconnected facts without understanding any underlying pattern you will slowly lose track of what goes where. For example, if I told you that the following series of letters O T T F F S S E N T E T T F F S S E N T was important; even if you believed me, correctly remembering them for ten years would be difficult unless you understood that the underlying pattern was that the letters were the first letters of the numbers from 1 to 20. It is easier to remember well-understood processes because the information to remember is only one of many examples that all work the same way and which follow a simple rule.

1. Demonstrations of, or Meaning of, Understanding

Based on a limited set of information from an original situation, we must be able to predict what will happen in a different situation by understanding the relevant factors and processes in the original situation, and how to adjust for the differences between the original and target situation.

The following capabilities, when taken together, define what it is to understand.

a. Describe

Given a language, a minimal understanding is exhibited by a description or a specification of which elements are contained in the set describing the entity and which are not.

b. Predict

The importance of prediction to science cannot be overstated. It is one of the most important products of science, because it provides the feedback necessary for self-correction (when a prediction fails, the theory or "understanding" which generated that prediction must be adjusted). Prediction assures systematic advancement rather than willy-nilly changes. In sum, it allows us to validate our understanding and be maximally prepared for the future. To predict is to specify what will happen in a new situation by virtue of understanding a rule that applies in a known situation; knowing how the unknown situation relates to the known situation; and knowing how to correct the rule if differences exist between the situations. For example, simply knowing that some pigeon pecked the blue light more slowly than a red light doesn't help predict much. But, understanding that the blue light signaled a decrease in reinforcement rate and that the effect was reliable and general enables you to predict into a very large variety of situations for all life forms, i.e., any situation that signals a decrease in reinforcement rate will be likely to control a decrease in response strength. Correct predictions verify that we correctly understand nature. As a second example, for those that understand the control of key pecking, comes the ability to predict life choices in college graduates.

c. Control

If you understand how something changes as a function of changes in something else, then you have the opportunity to modify its causes, which in turn allows you to modulate it or make it occur or cease. For example, if you want to decrease the proportion of responding to one alternative in a choice situation, you could decrease the reinforcement rate to that alternative, or increase the reinforcement rate to the other alternative.

If you do not understand what makes a phenomenon work you will be unable to control it. It will occur or not occur irrespective of your efforts.

d. Synthesize

If you understand what makes a phenomenon work, not only will you be able to create or abolish it as you desire, you will also be able to produce completely new variations to suit your needs. You will be able to produce a behavior in an organism that it previously did not do. You can teach someone to play the violin, run as fast as they can, or give up a life of crime.

e. Explain

To explain is to provide the causal factors pertaining to the phenomenon and to integrate the cause of a phenomenon within a larger context or paradigm that enables the process to be generalized to other situations. An explanation provides general rules in order to more easily describe, make predictions, control, and synthesize new phenomena and to communicate the requisites of this ability to other people. A proper explanation must be based on the criterion specified under truth: it must explicitly and unambiguously specify its elements, it must specify the functional properties of objective externalistic elements (i.e., empirical stimuli and responses) and it must be testable or capable of being validated. These factors are discussed in more detail in the chapter on explanation.

f. Coda: Understanding Versus Opinion and Delusion

Understanding a phenomenon entails substantially more than simply describing something. There is a wide variation in what people understand and how well they understand an issue. Many of the cues we take to indicate understanding can be memorized rather than understood. This is the essence of the dolphin metaphor. Figure 1.14 illustrates that issue.

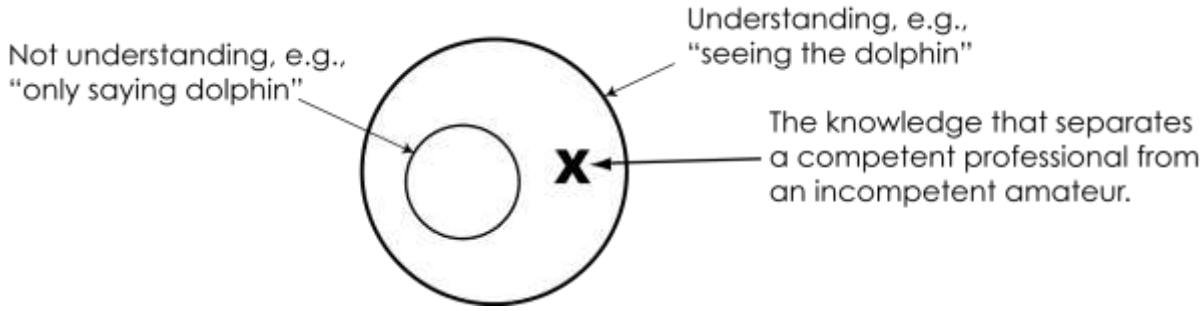

Figure 1.14 Understanding is substantially more than simply repeating the words used to label a thing. Understanding is also to be able to behave correctly with respect to the issue in a wide variety of circumstances.

IV. Science is the Label for the Activity That Gives You Your Best Bet to be That Which is Labeled Ethical and Prosperous

The fourth step in building a logical foundation for your practice of psychology is to do those activities which are known to produce, what people have labeled truth and understanding because that will give you your best chance to get what you want most (i.e., being ethical and/or prosperous).

Because science is the label for the human activity that produces what people mean by truth and understanding, it follows that scientific psychology gives you

the right to claim that you are ethical. While you could be a scientist and scientifically manipulate people out of their money (unethical), you cannot be ethical if you do not implement the most well proven procedure available.

Additionally, scientific psychology gives you the confidence to believe that you will be successful at your job (again because what you do is based upon the best available understanding of how things actually work but you could be foolish at business and lose money). In point of fact, science is the only activity that can give you your best chance to be ethical and prosperous. Note however that the focus of science is not on doing those things that make you ethical and prosperous, rather its exclusive focus is on reliability and prediction and all the rest.

When you wish to produce a product, then you do those activities that are known to produce that outcome. When you have a particular goal or destination in mind, you take the path that is known to go in that direction.

V.Conclusion

If you want to be ethical (e.g., do unto others as you would have them do unto you) and/or if you want to be prosperous (e.g., make money), then your practice of psychology should be scientific or behavior analysis. If becoming good at behavior analysis is difficult, recall that you are committed to do what it takes.

VI. Conceptual Follow-Up: Vocabulary Referents and Decisiveness of Arguments

A. Vocabulary Referents

The vocabulary accepted in the development of the thesis of the present chapter was that of everyday terms because it's essential to show that science is the best expression of what's at the heart of most people's beliefs, not something that is independent of them. Additionally, the use of common language was deemed reasonable because the label for sets is secondary to the understanding of what was in and not in those sets. Detailed definitions of those terms were provided because discrepancies in the degree to which different people have thought through the actual referents for those terms could be consequential.

The issue of the actual contents of referential sets is well illustrated by the term “sunrise” and the obligatory evolution of its referent. When the word “sunrise” was first coined, it referred to the sun rising in a high vertical arc above a flat four-cornered earth. When science replaced the notion of a flat earth centered solar system with the more appropriate sun-centered solar system and a rotating spherical earth, the referent of sunrise had to be adjusted. The core of the meaning of sunrise continued to refer to an increase in the illumination level

following a period of darkness that appears as if the sun is becoming more overhead but it no longer implies a sun rising over a flat earth. Rather, it refers to the rotation of the earth thus changing which part of the earth faces the sun. In effect, the exact opposite of a sun rising; "earth fall" would be a more accurate term with earth spin possibly the best. However, it would be awkward at best to say "let's go fishing when the earth turns sufficiently to first give us a line of sight to the sun" or to title a book about Franklin Delano Roosevelt "Terminator Crossing at Campobello." Terms such as truth, reality, and understanding do not currently refer to the correct referents for all users. However, eventually the referents for those words will be adjusted in light of the principles of science just as the referents for sunrise were adjusted to reality.

The difference between using well-evolved terms such as "sunrise" and terms with still evolving referents such as "truth" is that, it is very unlikely that you would be talking to someone who would take your use of "sunrise" as support for their flat earth view, and there are very few people who would presume that you believe in a flat earth-centered solar system just because you use the term sunrise. However, when you use a term such as "truth", you cannot presume that no one in your audience will misunderstand your meaning and that no one will presume that you have a poor epistemological foundation for your beliefs. Always clarify your meaning of terms whose referents are in transition or don't use those terms at all.

B. Decisiveness of Arguments

An unassailable and orthodox philosophical didactic could have been fastidiously expounded for the issues in this chapter but at the cost of expanding the treatment to hundreds of thousands of pages thus obscuring its relevance to psychology and making it completely opaque to its target audience (besides resolving nothing!). Many lifetimes could be (and have been) spent arguing philosophical fine points such as "what is real?" or "what is truth?" or "how do I know that the truck speeding toward me is actually real?" or "how do I know that this is not all just a dream?"

It is an absolute fact that, in principle, you cannot know with absolute perfect certainty that something is real or even if anything whatsoever is real. Ultimately, any test to establish that something is real would itself fall prey to the same criticism that caused you to test the original knowledge in the first place. You could be in a matrix in a matrix in a matrix.

This text uses as conceptual scaffolding the terms truth, understanding, and reality whenever it is pedagogically useful, whereas in actuality, science is simply the systematizing of the events we experience, thus making them predictable. From a scientific perspective, it doesn't matter if we are describing reality or the rules of the matrix or the rules of a matrix within a matrix. The notion of an ultimate reality is meaningless.

However, as a matter of pragmatic convenience, we will reject philosophical nihilism and accept that there is a position that can accept that we must avoid a truck bearing down on us without being required to run from ghosts. In other

words, things that most people who play by the rules enunciated in this chapter accept as real, are real.

The approach taken by the present text is that we can act as if what we label reality exists because it doesn't matter whether it exits or not. There is no practical negative effect of assuming that it actually exists if it, in fact, does not exist, given we establish its properties with the scientific method.

C. Cautionary Advisory

NEVER use every-day set names of complex concepts without defining them. Never presume that a listener has the same definition as you do, especially for the terms: ethical, reality, truth, understanding, or science.

Often scientists simplify their task on this matter by never using the terms. This has led to the unfortunate believe that some words refer to real things that are forbidden to science. Rather, it is the case that some people have the wrong definition for words and therefore believe in things that are not "real." Many scientists simply give up on the word rather than to try to explain the only meaning the words could have because it would take too long.

D. Coda

Few people would articulate their goal or onus as: "I want to be empirical, etc." But, most would say that they want to be ethical, as well as prosperous, and then go on to say that in order to accomplish those things, they base their practice of psychology on understanding the truth; and further, that understanding the truth is the primary product of science.

It is because of science's empirical track record in producing desirable results that psychology is moving toward science as fast as it can. It is not because of an allegiance to some noble sounding but arbitrary goal.

An important aspect in understanding the activity labeled science lies in the way it came about. It did not come into existence when some authority figure defined a creed called Science; and then began ordaining people as Scientists if they took the oath. Science came about when people who demanded to know what is generally meant by the term truth or reality and who demanded to understand what they were doing were seen as a group and came to be labeled scientists.

The procedures that avoided erroneous conclusions and which led to the most correct predictions came to be labeled the scientific method. In that sense, science is simply mankind's attempt to keep from being deceived by nature. As is developed over the course of this text, the results of the scientific method are the best information we have access to. You will see that truth or reality can have no meaning beyond what the scientific method reveals because there is no better method with which to determine what we label "understanding the truth".

When you have something important at stake you demand what you label

truth. You should be no less scientific when the body of knowledge or the welfare of your patient is at stake. The following anecdote illustrates that whenever it matters to you, you already know enough to demand the truth, and to understand what's going on (i.e., to be scientific). Suppose that you and I were going to bet $100.00 on the outcome of a coin toss. I flip; you call heads while it is in the air; it lands, I cover it, sneak a look, call it tails, and quickly put it in my pocket. You would not pay. You would demand that you see an outcome before believing it or you would require that trustworthy people see the outcome and report it to you. The fact is if you are uncertain what to do about something that is personally important, you appeal to direct observation as your final arbiter. It is what you can experience for yourself that ultimately determines what you accept as truth. If someone tells you something, you assess its truth by asking whether or not you can experience it directly or indirectly; whether there are several lines of evidence supporting it; whether the information is consistent with information from several other sources which are generally reliable or whether the information is consistent with what you already know is factual. When this informal notion of appealing to direct observation is used in an explicit, open, and consistent fashion, it is labeled the scientific method.

There is occasional resistance to the idea that psychology can be scientific. This resistance is based in a belief that behavior can never be understood. This objection typically takes one of two forms: that behavior is capricious and without a cause, or alternatively, that behavior can be understood only by methods that are incomprehensible, unlearnable, or innate in a few very special people. (Of course this latter view is typically argued most vociferously by people who think that they have that innate special skill.) The objections to scientific psychology are obviously not true when one considers the many professions that exist because of their ability to routinely change behavior on command, such as advertising, public relations, entertainment, education, and politics. However, even if the objections to the comprehensibility of behavior are partly true we should get on with understanding what we can understand, and not be stultified by what at best is only a half truth. We should assume that we could have an impact on behavior unless proven otherwise.

This chapter can be seen as having been the detailed axiom based deductive proof of why science is relevant to practitioners, applied researchers, and basic researchers in psychology. The following figure reviews the logic underlying the rationale for a reliance on science in psychology. Both set or concept names and their operational definitions are provided. Recall that concept names are nothing more than labels for the elements that make up that set.

Please take a few moments to go back over this chapter while looking at Figure 1.15 below.

VII. Schematic Review of the Logic of the Proof Showing That Science is Your Best Bet to be Ethical and Prosperous

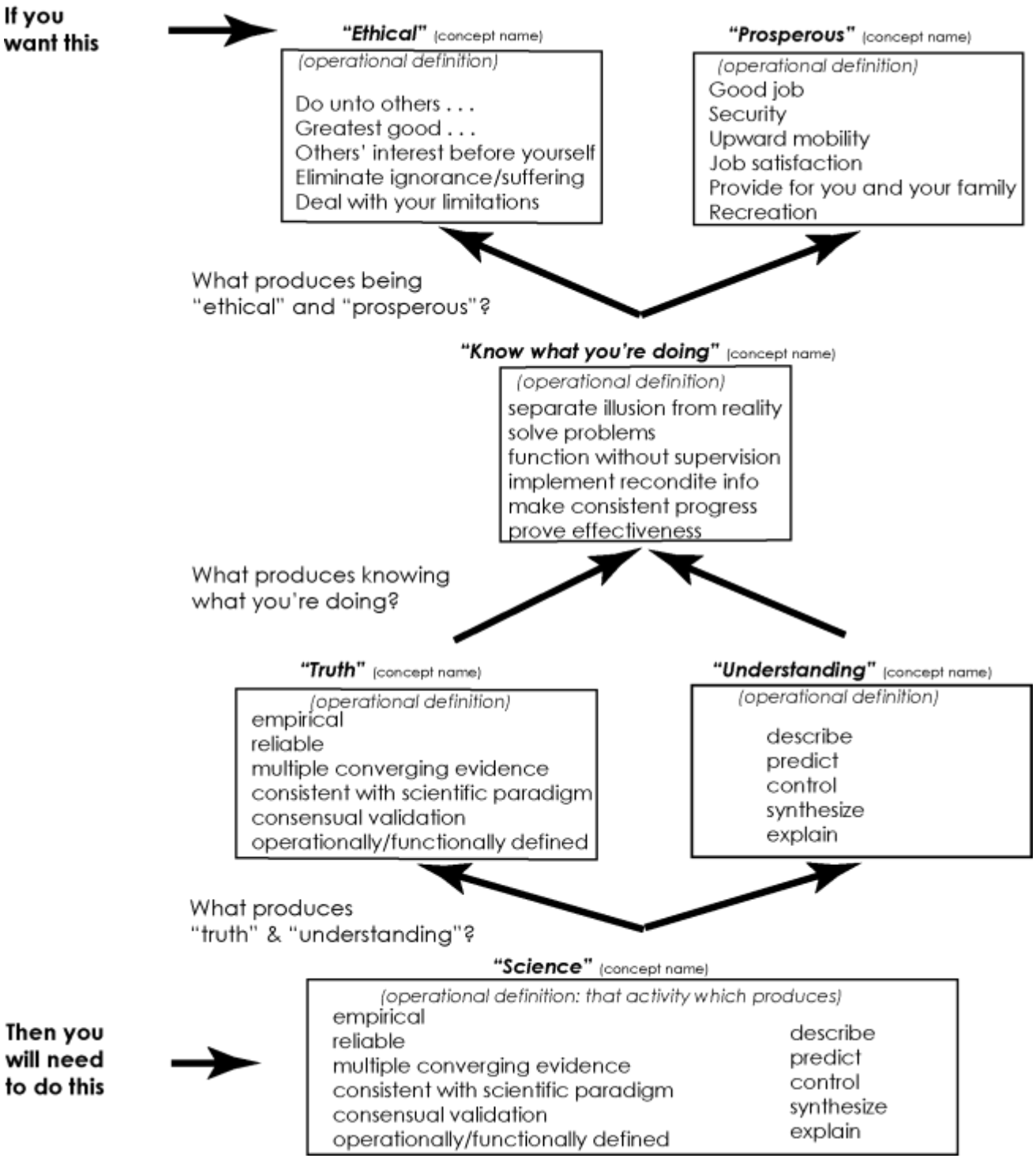

Figure 1.15 If you want to have, or be, the contents of the sets labeled ethical and prosperous, then you need to have what is labeled knowing what you're doing. If you want to know what you're doing, then you need to have what is labeled understanding the truth. Science produces the elements that have come to be labeled understanding and truth. Therefore, if you want the contents of the sets labeled ethical and prosperous, then you should do what is labeled science.

CHAPTER 2

Definition of Science

I. Characterization of the Products of Science

A. Truth / reality / facts
B. Understanding

II. Goals of Science

A. Research to understand (pure or basic research)
B. Research to solve a practical problem (applied research)
C. Dispensing solutions (practitioner / technologist)
D. Conceptual review: Contrasting goals of basic research, applied research, and practitioning
   1. a mundane example
      a. conceptual analysis: focus on practitioning
      b. conceptual analysis: focus on applied research
      c. conceptual analysis: focus on basic research

III. Lexical Definitions of Science

IV. The Essential Purpose and the Component Elements of Science

A. The universal set: all human endeavors
B. The set containing science: asking why
C. Subset defining science: correct answers to why
   1. understanding the truth is the best possible answer and characterizes the product of science
D. Preview: the problem addressed by science: changes or variance in nature
E. Preview: the process of science: best discovery process
F. Preview: the product of science: knowledge and explanation
G. Summary

V. Assumptions of Science

VI. Prescripts of Science

VII. Misconceptions About Science

A. Accumulation of facts is not the primary goal of science
B. The discovery of the unique or inexplicable is not the object of scientific research
C. Science is not primarily concerned with providing for people's needs
D. No science is exact
E. Science does not have the obligation to disprove anything
F. Both science and art consider only one thing (or very few things) at a time
G. Theory and the "real world" are not different
H. Science is not in search of the real world

VIII. Motivations Driving Scientists

IX. Impact of the Decision Strategy on Progress in Understanding Nature

A. Impact of decisions based on a principled logical feedback process (scientific approach)
    1. how a principled system works
        a. example where identification of necessary and sufficient conditions is essential
        b. example where efficient correction of principles requires a clear understanding of the theoretical system
        c. example where the structure of a principled explanatory system must efficiently eliminate both false positives and false negatives
        d. a simplistic example from the early evolution of a principled behavior analytic explanatory system
        e. an example of a counterintuitive principled prediction in the field of learning that is correct
    2. overview of the impact of principled systems
B. Impact of decisions by whim, guess, or intuition (eclecticism)

X. Paradigms: The Optimizing Mechanism Underlying the Evolution of Our Understanding of What We Label Reality (i.e., Science)

A. Introduction and Overview
B. "The Structure of Scientific Revolutions"

1. scientific history as paradigms and paradigm change
    a. conceptual reminder: the behavior analytic paradigm
2. the emergence of a paradigm
3. the everyday conduct of science or normal science
    a. the priority of paradigms
    b. normal science as puzzle solving
    c. dilemma of necessity to advance our knowledge base, but even greater necessity to resist mistakes or getting sidetracked
4. paradigmatic failure and the emergence of scientific revolutions
5. paradigmatic revolution as a fundamental change to an incommensurably different worldview
6. summary
    a. what is a paradigm?
    b. both normal science and paradigm revolution can be seen as hill climbing based on the most valid information available
        i. normal science or within paradigm hill climbing
        ii. paradigmatic revolution or between paradigm hill climbing
    c. a paradigm supports the validity of its principles and provides the ability to extend those principles into new situations
    d. why is the existing paradigm always presumed to be correct?
    e. a paradigm's description of reality must in some ways be considered as more fundamental than direct experience

CHAPTER 2

Definition of Science

Finding out that being scientific will best solve your onus to do what it takes to be ethical and prosperous only gives you a reason why to do science and why not to have non-scientific explanation for things; but it does not help a lot in understanding what science is, or the best way to actually do science. This chapter is to give you more information about science so you can know more about doing and understanding those things which are best able to make you ethical and/or prosperous.

This chapter is a more complete elaboration of the process of science than Chapter 1. It could be seen as an operational/functional definition of science. This chapter is provided because the more you know of the tool "science"; 1) the better you can use it to accomplish your ends, 2) the better you can use the knowledge that science produces, and 3) the better you can avoid things that are not necessarily true but seem true. This systematic elaboration of the process can be accomplished by way of elaborating the definition of science.

As you realize, or at least suspect by now, science is very much more complex than some simplistic definition that you can memorize and then put the issue away, such as when someone simply learns to say "dolphin" when presented with a SIRDS with a dolphin in it. The following material is an attempt at applying words to what science is so that you can gain the knowledge through indirect experience rather than actual experience (the hard and slow way).

I. Characterization of the Products of Science

A. Truth / Reality / Facts

Science produces "facts which are known to match what is labeled reality" or that the events are:

Empirical
Reliable
Multiple Converging Evidence
Consistent with the Paradigmatic Framework Labeled Science
Consensually Validated
Operationally/Functionally described

B. Understanding

Science produces knowing the relationship of facts to each other or the processes underlying phenomena or that you can:

Describe
Predict
Control
Synthesize
Explain

II. Goals of Science

The process of science typically has one of three goals.

A. Research to Understand (Pure or Basic Research)

Pure research is concerned with developing valid, complete, and coherent descriptions and explanations. It is interested in organizing data into the most general and parsimonious laws or qualified statements of uniformity. The emphasis is on comprehension or understanding. It is motivated by curiosity and inquisitiveness about natural phenomena. It is interested in data and relationships for their own sake. Most often the details of the research are considered arbitrary; the fundamental process is the focus. For example, in operant research, a pigeon pecking for food is the arbitrary, irrelevant aspect; behavior under the control of reinforcers is the important point. Doing basic research is like learning a language; once it is known, all things can be done. Benjamin Franklin was engaged in pure research when he tried to compare lightning with static electricity generated by feet rubbing on a rug. He did not do it to find a better way to illuminate Philadelphia at night nor how to make a smart phone. He just wanted to "know." It is interesting to note that 200 years later, few Americans would survive a single year if electricity suddenly disappeared altogether. The practical impact of his indulgence of his curiosity is almost unimaginable. His discoveries are all the more impressive considering that his only reason was to add to the knowledge base. He did not do it for the money. He would not have had an answer to a critic who opined: "just how will this help the human condition and if you don't know, then you should do something more practical." Studying the nature of cell growth would be pure research. Trying to describe and understand the determinants of the organization of behavior in time would be pure research.

B. Research to Solve a Practical Problem (Applied Research)

Applied research is concerned with the discovery of solutions to relatively specific practical problems and places its emphasis upon those factual data that

have immediate utility or application. The emphasis is on control. Applied research is like learning phrases needed to accomplish a variety of specific things in a foreign language without necessarily actually being fluent in the language. The search for a cure for cancer is an example of applied research; discovering a solution for manic depression is an example of applied research.

C. Dispensing Solutions (Practitioner / Technologist)

Practitioners are concerned with the direct application of principles and theories from one or more fields of science for the purpose of dispensing solutions to problems or individuals rather than being concerned with the discovery and organization of knowledge. Their task is to make a problem go away one way or the other and as efficiently as possible and to not make things worse. Strictly speaking, a practitioner is not a scientist, but that is not to say they are necessarily unscientific. Practitioning is like memorizing sounds of a song in a foreign language without necessarily knowing the language. It accomplishes an immediate specific end. While a practitioner may uncover a phenomenon of great importance to the understanding of nature, that is not their primary focus. In point of fact, their training does not always give them the ability to recognize a new fundamentally significant phenomenon even if they saw it. A practitioner or technologist administers chemotherapy or psychotherapy. A physician or a psychotherapist is a practitioner.

D. Conceptual Review: Contrasting Goals of Basic Research, Applied Research, and Practitioning

1. A Mundane Example

Suppose you knew a grade school teacher having trouble teaching spelling to Johnny. You suggest that they follow correct spelling with a positive consequence such as praise and thereby reinforce (or increase) the rate of correct spelling. A week later, the teacher reports that it did not work.

a. Conceptual Analysis: Focus on Practitioning

In this case, your primary goal is to get Johnny to spell correctly. It is presumed that the rate of an individual's behavior is a function of its consequence. You suggest some other procedure such as; test Johnny when alone, provide the whole class with a positive outcome when he spells correctly, or give Johnny "free time" as a consequence.

b. Conceptual Analysis: Focus on Applied Research

In this case, your primary goal is to find out what about classroom dynamics interfered with the reinforcing effect of praise for spelling correctly so that other teachers with similar problems can use the intervention. It is presumed that the

rate of an individual's behavior is a function of its consequence. You suggest that the teacher closely observe what happened when praise was given. Was it a positive outcome? What did the class do, support or ridicule Johnny? What did Johnny do? What happens when some other type of good outcome is used?

c. Conceptual Analysis: Focus on Basic Research

In this case, the primary goal is to find out how an outcome becomes functionally positive or negative and if positive can its effectiveness be modulated by other concurrent outcomes such as a punisher? It is presume that the rate of an individual's behavior is a function of its consequences. Basic research is typically done in highly controlled situations (pigeon models in experimental chambers) with highly controlled procedures (computer controlled repetitive trials) so that reliable and generalizable strong conclusions can be drawn.

III. Lexical Definitions of Science

These dictionary-type definitions attempt to communicate with "25 words or less" what science is all about. They are not laid down by some authority such that if you stay within the letter of a definition, then everyone is obligated to call you a scientist. They only characterize science in broad strokes and don't attempt to cover the enormous number of subtle aspects of science which are consequential in the actual practice of science. The following are lexical definitions of science.

- "Science is not so much concerned with accumulating highly precise and specific data (although it is necessary) but rather science seeks to discover uniformities and to formulate statements of uniformities and consistencies of relationship between natural phenomena."
- "Science uses unconfounded empirical tests to develop, discover, and explain systematic frameworks within which relationships can be explored."
- "Science is a knowledge generating activity that is based on systematically organized bodies of accumulated knowledge obtained through objective observations."
- "Science is to understand, explain, and predict by specifying the systematic relationships among empirical variables. It must be consensually valid and general."

IV. The Essential Purpose and the Component Elements of Science

After depicting where science fits within all human activities, this section previews the problem to which science addresses itself, and the process whereby

science accomplishes its product. They are developed more fully in subsequent chapters.

A. The Universal Set: All Human Endeavors

Consider all possible human endeavors including such things as art, war, fishing or love as points arranged into a line as illustrated in Figure 2.1.

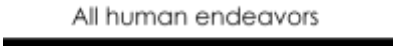

Figure 2.1 All human endeavors could be depicted as points on a line.

B. The Set Containing Science: Asking Why

We choose one of those activities or one point. We choose the human activities that can be labeled "the search for an answer to the question why?" We want to know why butterflies change, why the sun rises, why we live, why we have war, or why we love. We could zoom in on, or expand all the various whys out to become its own line made up of many instances.

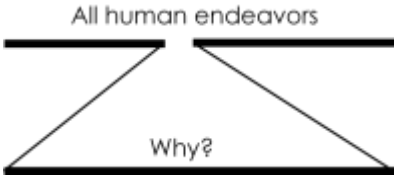

Figure 2.2 One human endeavor is asking why. There are many many different intents or objectives to the question why. They could be depicted as points on a line.

C. Subset Defining Science: Correct Answers to Why

Of all aspects of the question "why," we are interested in answers not the purpose of the question or the ways to articulate it. Each why could be seen as having thousands of different kinds of answers. Each of those answers could be depicted as a dot and all possible answers to each why could be seen as a line.

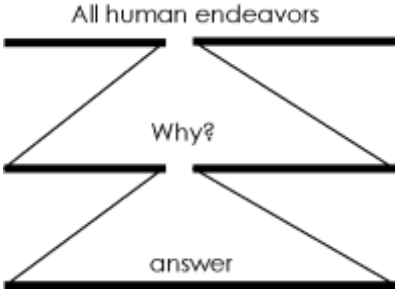

Figure 2.3 One intent of asking the question "why" is to come to understand the answer. There are many different types of answers. They could be depicted as points on a line.

1. Understanding the Truth is the Best Possible Answer and Characterizes the Product of Science

Of all possible answers to the various whys, we want the best. In everyday language, we want to understand the truth, the whole truth and nothing but the truth. If the answer is only a guess, we want to know that it's only a guess, so we can proceed on to find the real answer. In the previous chapter, we logically developed the case for why science is nothing less than the production of what are generally considered the best possible or "satisfactory" or "acceptable" or "truly understood" answers. Science is man's attempt to develop a perfect predictive model or find and understand the truth by obtaining the best answer to each of its whys.

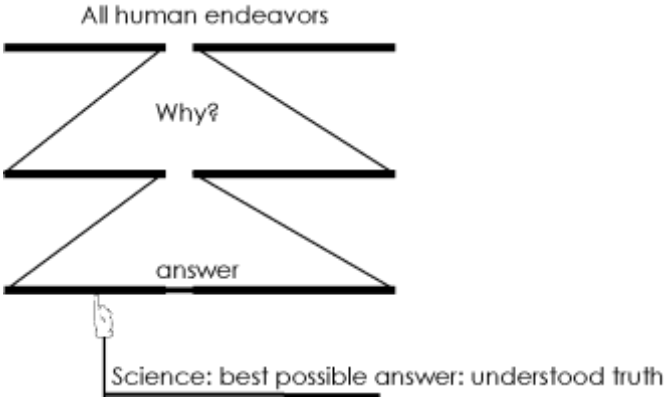

Figure 2.4 Science has been shown to provide those things labeled the best possible answer or understood truth. It is one of the many possible answers.

Science is the human endeavor that asks why things are the way they are, and what answers that question with the best available valid integrated answer (i.e., understood truth).

D. Preview: The Problem Addressed by Science: Changes or Variance in Nature

To elaborate the elements of science, we can detail the PROBLEM to which science addresses itself by considering the meaning of the term knowledge. In preview, science addresses itself to variance in nature – why things are one way in one situation and another way in a different situation. This element will be discussed in Chapter 5.

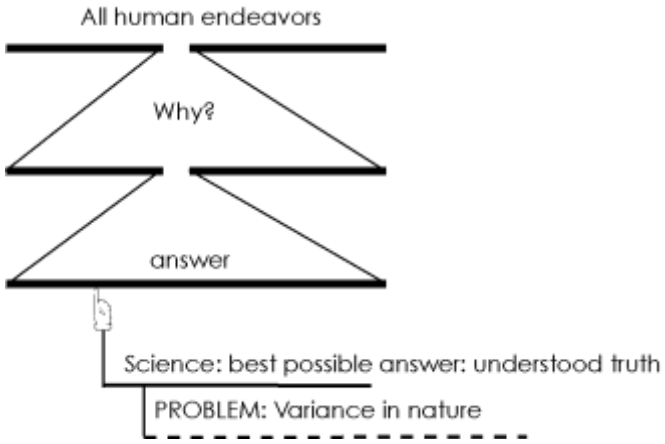

Figure 2.5 The major components of science includes the PROBLEM to which science is addressed. That problem is variance in nature.

E. Preview: The Process of Science: Best Discovery Process

To further elaborate the elements of science, we can detail the PROCESS that produces the products of science by examining what procedures provides the best possible answers. These elements will be discussed in Chapters 3 and 11-14.

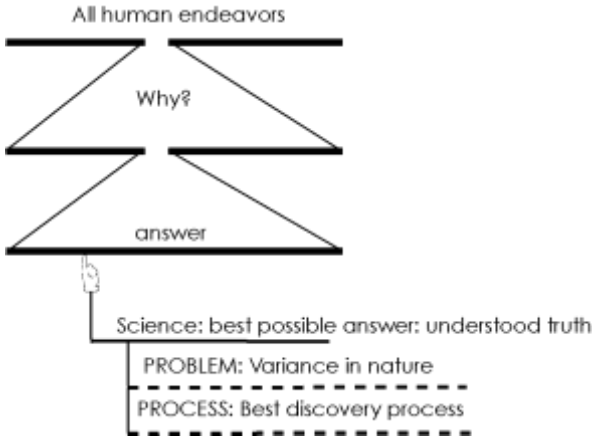

Figure 2.6 The major components of science include its PROCESS which is the best discovery process available.

F. Preview: The Product of Science: Knowledge and Explanation

To elaborate the third element of science we can detail the PRODUCT of science by examining the meaning of truth and understanding or knowledge and understanding. This issue is covered in Chapters 5, 6, 7, 8, and 9.

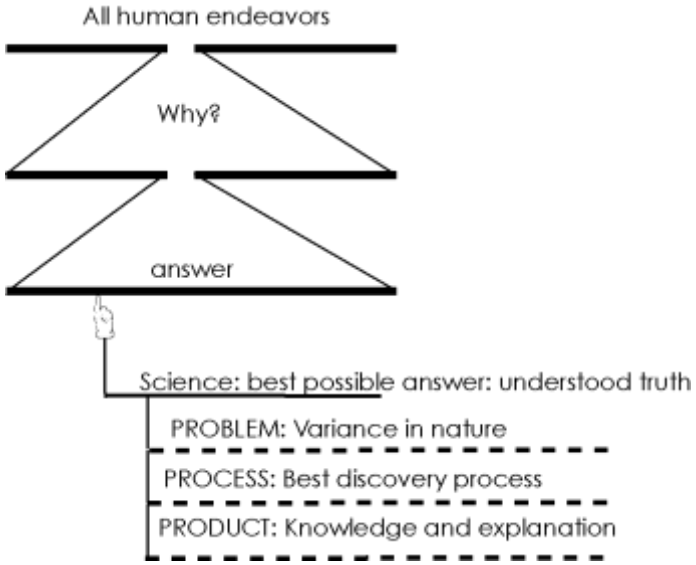

Figure 2.7 The major components of science includes its PRODUCT which is knowledge and explanation.

G. Summary

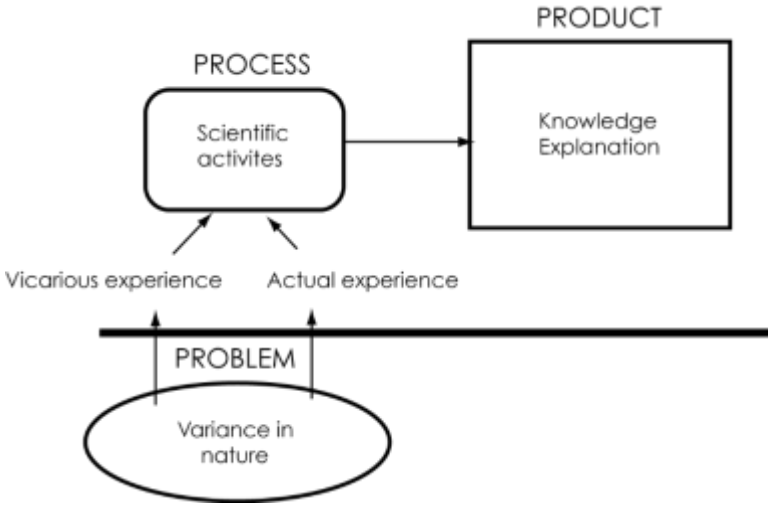

Figure 2.8 The scientific activities or the PROCESS of science addresses variance in nature That variance is obscured and difficult to understand. It's as if it is seen through a glass darkly. That variance or the PROBLEM to which science is addressed is understood through actual and vicarious experience. The process of science produces the PRODUCT of science: knowledge and explanation.

V. Assumptions of Science

As an alternate way to communicate the nature of science, its basic assumptions or what science pretty much takes for granted can be specified. These are issues that are so fundamental as to be virtually unprovable, therefore, in the absence of contravening proof they are assumed to be true.

A more punctilious or inarguably correct way of stating the above is to say that science acts as if the following statements are true (e.g., this all may be a dream but these relationships seem to be invariant [i.e., what we mean when we label something as real] within the dream and we can't really get out of the dream).

Regardless of whether the assumptions are ultimately real or not, if you flout or violate the assumptions of science you will have trouble convincing others of the merits of your work. For example, if you reject the space/time continuum and explain the characteristic pause preceding a procedure requiring a large fixed amount of work (a pre-run pause in fixed ratio schedules) by saying: "the space/time continuum is temporarily changed by the presentation of a reinforcer. The pigeon is actually responding at the same rate. What we're detecting is an alteration in the space-time continuum." Most reasonable people will think you are wacky.

Just because you can imagine the possibility that the fundamental "assumptions of science" are wrong does not make it worth acting as if they are in fact wrong whenever it is convenient. You cannot get very far without any commonly agreed to foundation.

The following are examples of what could be considered the assumptions of science.

Space is real.
Time is real.
Matter is real.
What exists, exists in some amount.
The universe can be described in an orderly manner.
All events are determined.
Humans are capable of understanding their universe.

As has been already pointed out, none of these assumptions need be accepted as ultimately true; all can actually be seen as nothing more than the "best" way of saying that nothing has been presented that would force us to invalidate any of them. They are a pragmatic convention, convenient for most situations, the reality of which is irrelevant.

Nothing is lost from the common level meanings of "the real-world" if reality is considered only a construct, but one that is so pervasive and so reliable and inviolable that serious disagreements very rarely result in any practical change.

This issue will be covered in more depth in Chapter 7.

VI. Prescripts of Science

A fifth way to view science is in terms of its rules of behavior or attitudes, directives, guides, or instructions to its practitioners, such as "you must be very scrupulous about the accuracy of your methods" or "you must be impartial." These are statements of what has been shown in the past to most efficiently lead to what is labeled understanding the truth.

Science has been impartial and impersonal.

Science has not been involved with morality.

Science has maintained vigilance over its method.

Science has suspended judgment when its models are insufficiently reliable.

Scientific belief systems are simultaneously absolute and tentative. (The dynamics of this seeming oxymoron is covered in the subsequent section on paradigms.)

Science has consistently demanded that its knowledge base be true (i.e., be empirical, reliable, have multiple converging evidence, be consistent with the scientific paradigm, be consensually validated, and be based on operationally/functionally defined terms).

Science has consistently demanded that its practitioners understand its knowledge base: (i.e., require that practitioners be able to describe, predict, control, synthesize, and explain events and processes).

VII. Misconceptions About Science

There are many misconceptions about the nature of science. Science can be defined in terms of what it is not.

A. Accumulation of Facts is Not the Primary Goal of Science

This misconception is one of the major stumbling blocks for beginners. The discovery of the unifying principle is the essence of science rather than finding some isolated facts. Isolated facts are only of value if they allow the development of a better unifying principle otherwise they are valueless. Any particular functional relationship between some specific stimulus and a specific behavior is of little consequence (e.g., the pigeon pecked the blue key slowly). Of very great importance is a particular functional relationship as an instantiation of a more fundamental, more general relationship between very large classes of events (e.g., the rate of behavior is controlled by its relative reinforcement rate). It is the general rules or unifying principles that are of value.

B. The Discovery of the Unique or Inexplicable is Not the Object of Scientific Research

Similarly, the unifying principle is the goal of science rather than the identification of the inexplicable. The inexplicable act is only of value if it allows the development of a better unifying principle, otherwise it is valueless. The task of science is to see the commonalities in very diverse phenomena and to show how the apparently "inexplicably different" are actually examples of the same laws. Recall Newton, an apple and the moon.

C. Science is Not Primarily Concerned With Providing for People's Needs

The task of science is to understand the universe, not to fix people's problems. (See the Goals of Science section above.)

D. No Science is Exact

All sciences are empirical and empirical reality has an infinite degree of precision (e.g., the exact weight of an object would be an unobtainable infinite number.

E. Science Does Not Have the Obligation to Disprove Anything

The burden of proof is on the unusual assertion not the well-documented body of knowledge. Otherwise, progress on understanding real issues would be sidetracked. (See the subsequent section on paradigms.)

F. Both Science and Art Consider Only One Thing (or Very Few Things) at a Time

Science attempts to understand a phenomenon by assessing the impact of one variable or a very few variables at a time. It's often erroneously said that the difference between art and science is that science can only examine one thing at a time and therefore science is limited. However, a painting or a poem can only be of one thing at a time also.

G. Theory and the "Real World" Are Not Different

To say it works in theory but not in the "real" world is to misunderstand the process of science. Unsurprisingly, the person who asserts such a notion invariably believes their shallow assessment of "the real world" is more correct than "the theory," or as a minimum that they actually have the authority to tell others that something works in theory but not in the real world. If a theory does not predict in new situations, a key element is obviously missing. One that either the speaker forgot, never understood in the first place, or, more rarely, is one that no one suspected before and is absent from the theory. In any case, the discrepancy must be resolved.

H. Science is not in Search of the Real World

There is no arbiter of the real world. Who would you ask "is this reality or just an illusion"? The best you could ever have is that your predictive models are always right, and as a result those predictive models would define reality at that point in time.

VIII. Motivations Driving Scientists

Yet another perspective would emphasize the motivations underlying a scientist's behavior.

It is the case that if you want to be either or both ethical and prosperous, then being a scientist is your best bet. This is especially true if your primary interests are applied. However, many scientists have an additional reason for choosing science.

Many scientists are driven by a curiosity about how things work. They ask the question "why." They are motivated to know why things work the way they do and nothing less than the truth will do for an answer. Their goal is to minimize the mysteries in the universe by obtaining knowledge through direct observation of particular aspects of the universe.

Scientists work very hard at unraveling the universe by using known and accepted principles. For example, beginning with the theory that matter does not disappear, a scientist may try to unravel a performance of a magician. Demonstrating exactly how the trick worked with known and accepted principles of physics would prove the scientist an expert puzzle solver. Alternatively, starting with the assumption that people are dying as the result of some pathogenic organism, a scientist can set out to solve the puzzle of just how they are dying and what will stop it. "The challenge is to succeed in solving a puzzle that no one before has solved or solved so well."

Thomas Kuhn (1962) eloquently made an excellent case for the view that science can be seen as a game or as puzzle solving in that it has rules and is intrinsically fun. That is not to say however that it is messing around or that it is not laborious. "For the scientist who plays the game for understanding rather than practical advantages, it is a game whose chief delights are the addition of one neatly contrived stroke that helps give form to a picture. A game affording a glimpse of what no one has conceived of before. A game from which may come the ecstasy of bringing order out of chaos."

In this regard the goals of science can be recalled. Basic research is the attempt to solve the puzzle of nature

IX. Impact of the Decision Strategy on Progress in Understanding Nature

A. Impact of Decisions Based on a Principled Logical Feedback Process (Scientific Approach)

Behavior analysis, like any science is based on the realization that the enormous variety of phenomena in the field are the result of a limited number of fundamental processes interacting in a limited number of possible ways. Those processes and interactions have non-random results and those results follow specifiable rules. The view is that causation is reliable and that Euclidian like logic can be used to advance our understanding from fundamental research findings to statements of general principles of causation and expected results.

As a principled science, behavior analysis first reduces the broadest possible set of behaviors to a minimum number of empirical externalistic functional relationships or processes (such as reinforcement and stimulus control). Those processes have defined properties. These systematic processes or principles are used to explain behaviors in the natural world, and to create a principled system with which to generalize or predict and under what conditions those behaviors will occur in the future.

1. How a Principled System Works

Perhaps the best strategy to use to develop an understanding of how a principled system works is to review a variety of metaphors each well illustrating an aspect of a principled system.

a. Example Where Identification of Necessary and Sufficient Conditions is Essential

A necessary condition is one where the outcome cannot occur without it. For example, oxygen is necessary for a flame - without it a fire cannot occur. A sufficient condition is where the outcome will occur with it, but the outcome will also occur with other sufficient conditions, for example, a fire can be started with a spark or a match.

This aspect of a principled system is well illustrated by a AI medical diagnostic system. It would be to create the database and the best prediction algorithm based on the existing data, for example “if child and red pimples” then predict chicken pox. The second step is to compare the predictions to the natural world and collect information to make the decision more accurate, more complete, and to better characterize the necessary and sufficient conditions for each. For example, while chicken pox is more likely in children, adults also get it and red pimples may also be acne. The point of the system is to avoid false positive and false negatives and to avoid having to depend on someone’s “good judgement.” Whatever information the physician would use with their good judgement needs to be formalized and put

into the diagnostic program. Examples would be the patient's temperature, the presence of VZV virus and any other chicken pox cases in the vicinity. It is fatuous to believe that a physician has some special magic underlying decision skill that a computer program could not have. A principled medical diagnostic system would inevitably evolve to always make perfect predictions: no false alarms and no misses.

b. Example Where Efficient Correction of Principles Requires a Clear Understanding of the Theoretical System

This aspect of a principled system is given by the guess-the-number-I-am-thinking-of-game. In it one person [playing the part of nature] thinks of a number from one to a million. (*That number could be seen as some functional relationship in "reality".)*

The second person [playing a scientist] guesses a number *(makes up a theory about or explanation for what "reality" is or how it works).*

The first person then says "you are too low (high)" "or says "you are correct" *(the first person's response is how well the theory matched reality*).

Then, the scientist adjusts their guess based on the feedback of the guess (*results of the research*), the scientists adjusts their guess *(explanation or theory*) in the direction that will more correctly characterize the number (*functional relationship in reality)*, and guesses (*does research*) again.

Person 1 [event in nature]		**Person 2** [scientist searching for truth]	
Actual Behavior	**Comparable Scientific Behavior**	**Actual Behavior**	**Comparable Scientific Behavior**
Choose a random number from 1 to 1 million	Some unknown phenomenon in nature that needs an explanation		
		Guess best number based on a clear and complete understanding of how numbers work (a number between 1 and 1 million and that the numbers are transitive therefore a binary search is the best solution strategy	Develop best explanation for the phenomenon based on a clear and complete understanding of how nature works and the given task
Respond high, low, or correct	Research outcome provides feedback of how well explanation works and points toward what to do next		
		Guess best number based on feedback from first guess and understanding how numbers work	Develop the best explanation for the phenomenon based on a clear and complete understanding of how nature works and feedback from the research
Etc	Etc		
		Etc	Etc

Figure 2.9. Detailed actual steps of guessing a number metaphor and their referent in science.

It should be obvious that in each case: 1) the question *(research*) must be explicit. A question such as "is the number either big or small" would not be a very productive guess because the answer would always be "yes" and 2) the answer *(results of the research)* must be definitive. An answer such as "maybe it is right,

maybe it is wrong: is not a very useful answer. When research does not produce a definitive answer for whatever reason, it is considered ineffective research. Any latitude in the predictions of a theory or latitude in the interpretation of an experiment translates to vagueness in the information produced by the research.

How the feedback obtained as the result of the scientist's guess is used to advance the knowledge base (explanation for the functional relationship *reality)* is also an essential aspect of efficiently finding the number. If the guess *(theory)* is 500,000 and the answer to the question is "too low" *(the results from the research*); then the next guess in the number guessing game should be in the middle of the range of remaining numbers so the guess should be 750,000. Guessing any arbitrary number larger than 500,000 such as 500,001 or even 750,001 is inefficient when guessing numbers. The experiment can be amateurish and a waste of time or it can be clever and elegant. The ability to do clever and elegant research is based on a clear understanding of the paradigm within which the research takes place, a comprehensive knowledge of what has been proven to date, and the ingenuity of the researcher.

The applicability of the number guessing game metaphor to research and a principled explanatory system for a systematic world is based on: first, the fact that the numbers from 1 to one million have a systematic relationship. The numbers are transitive (e.g., 2 is always bigger than 1), and secondly that the guesses are based on understanding that transitive system (e.g., 2 is always bigger than 1).

A principled feedback system enables guesses or research into the nature of the correct explanation to always move the knowledge base successively closer to the "true" explanation.

c. Example Where the Structure of a Principled Explanatory System Must Efficiently Eliminate Both False Positives and False Negatives

A flow chart well illustrates how each additional piece of information and its resulting change in the principled explanatory system moves the knowledge base a step closer to ultimate truth or the correct explanatory system.

Flow charts can be used to illustrate an explicit feedback-based decision process because they can be as complex as is necessary to specify a principled algorithm with which to make decisions. The essential element is that if a mistake is made or the outcome is wrong, then like a principled explanatory system a flowchart can be easily fixed because each decision that led to or permitted the error in prediction can be identified and corrected to assure the correct outcome next time, or at least the best outcome possible given the existing knowledge.

As a mundane example, a principled approach to choosing a pet could be created. Figure 2.1 shows several steps in the evolution of a principled way to find an acceptable pet.

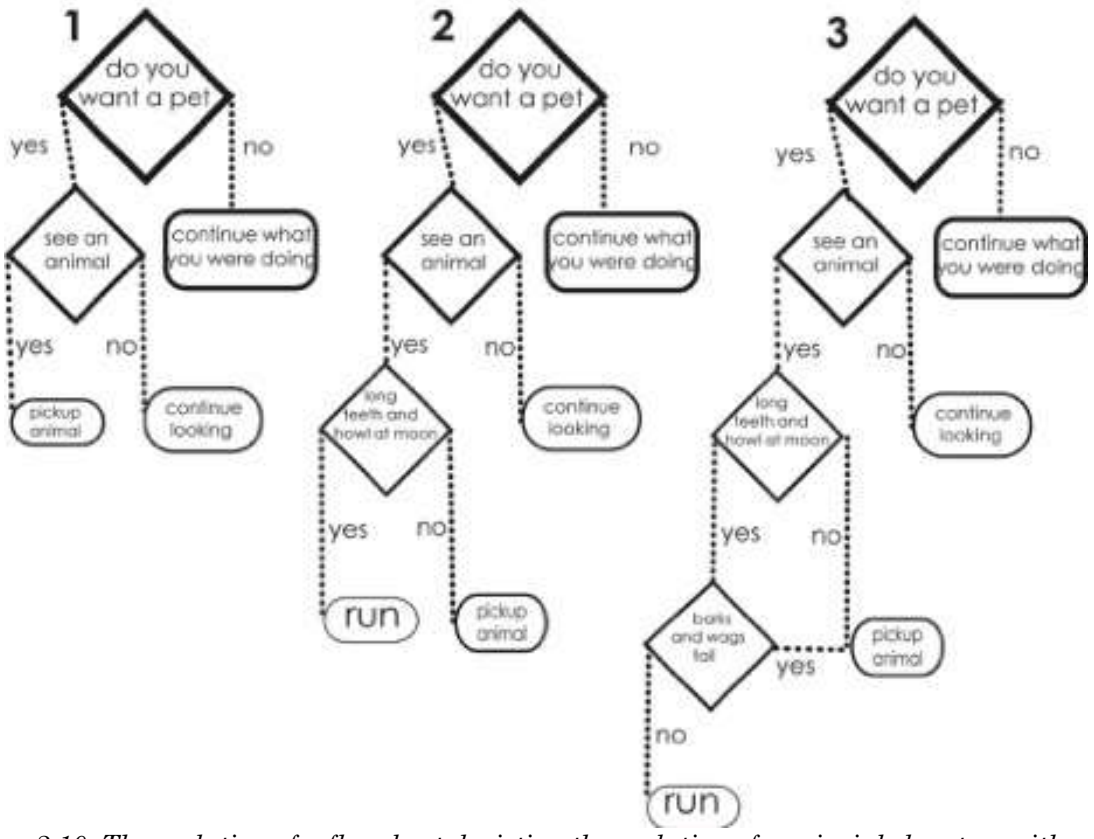

Figure 2.10 The evolution of a flowchart depicting the evolution of a principled system with which a pet can be obtained.

The initial principled system in Flowchart 1 is an algorithm which is the best initial attempt to get a pet (*explain a functional relationship*). This system was adjusted with procedure 2 after the error of picking up a werewolf and is depicted in Flowchart 2. Flowchart 2 eliminates the false positive possibility of picking up a werewolf. Flowchart 3 eliminates the false negative possibility of rejecting all dogs. Additional steps could be used to select only specific kinds of dogs or provide for the possibility of a goldfish as a pet.

The flowchart metaphor makes it easy to see what additional decisions could be added to eliminate false positives and false negatives. This aspect of the metaphor well illustrates the need to make an explanatory theory for events in nature neither explain too little nor explain things that don't happen.

d. A Simplistic Example From the Early Evolution of a Principled Behavior Analytic Explanatory System

An early explanatory principle in behavior analysis was that stimuli that were present when pecking was followed by food would, when presented again, control pecking. Stimuli in whose presence pecking was never followed with food in a simultaneous discrimination procedure would control not pecking. This "principle of discrimination and least effort" was used to **explain** why in a simultaneous red no food/green food discrimination, pecking occurred to the green key and not to

the red key or if food followed green and not nine other randomly presented colors, then pecking would occur only to the green key. As conceptualized this explanatory principle was wrong. If a sequence of those same ten stimuli are presented in order across a repeating interfood interval (a serial discrimination) (e.g., food, red, green, blue, vermillion, yellow, purple, orange, lime, turquoise, amber food ... red, etc.) key pecks will occur to purple, orange, lime, and turquoise even though none had never been present when food followed a keypeck. No peck was ever followed by food when they were on yet they controlled reliable responding for hundreds of sessions. It is beyond the scope of this text to present all the issues bearing on this functional relationship, but simply put, stimuli correlated with the better half of a schedule of reinforcement will control the reinforced behavior.

e. An Example of a Counterintuitive Principled Prediction in the Field of Learning That is Correct

The Rescorla-Wagner model of Pavlovian conditioning provides an easy to understand example of a principled model in psychology. It states that each reinforced trial will change the strength of a behavior toward an asymptote. The magnitude of that change is some proportion of the difference between the current strength and the asymptotic strength. For example, during conditioning trials, if the original behavior were 0, the asymptotic behavior were 100, and the increment was 10% then on the first trial, the change in strength would be 10% of the difference between 0 and 100 [.10(100-0)] or 10. The second trial would increment the response strength 10% of what is left or increment the response strength to 19 {[.10(100-0)] + [.10(100-10)]}. The response strength after the third trial would be 27 {[.10(100-0) + [10(100-10)] + [.10(100-19)]}.

Secondly, the model states that the strength of behavior is the sum of the strengths to each of the conditioned stimuli in the environment. If two different stimuli were separately conditioned to a strength of 35, then when both stimuli were present together the strength of behavior would be 70, and the remaining discrepancy to the asymptote would be 30.

The interesting, unanticipated, and counterintuitive, but principled prediction is that if two different stimuli are each separately conditioned to a strength of 100, and then combined and the two stimuli together were reinforced for additional trials; then when each of those stimuli were subsequently tested in isolation, they would each exhibit an asymptotic strength of only 50. The reason is that when two stimuli each are conditioned to 100 and then combined, the conditioned strength is 200, while the asymptotic limit is only 100. The theory requires that each reinforced trial move the total conditioned stimuli toward 100 which requires each reinforced stimulus to drop to a strength of 50 so that when combined the total conditioned strength is at the asymptotic limit which is 100. This is a case where reinforcement weakens behavior, and is a quintessential example of a principled scientific prediction.

2. Overview of the Impact of Principled Systems

The point of a principled explanatory system is to have a system that is guaranteed to move closer to a correct and perfect explanation with each piece of new information. The result of research findings must clearly move us toward the final explanation. In the number guessing game, each guess efficiently narrows down the range of possible numbers that are correct. The guessing game metaphor for an eclectic unprincipled explanatory system would be any game where you cannot get closer to the goal with successive questions and answers. Such a game could be created by having a list of one million random unrelated things (e.g., a rock, a tree, the color red, electricity, etc.). The questions could be "glass?", or "music?"; the answers could be yes or no. Each question and answer are independent and successive information does not systematically close in on the correct answer. Over multiple guesses there would be no transitive progress, you would not be getting meaningfully closer to your goal (each step will only advance 1 step in a million).

The structure of a principled science enables systematic progress because the elements and processes are clearly and explicitly articulated and testable. They have formal properties which cannot be informally changed in incompatible ways to suit each situation. They are accountable. Explicit predictions can be made based on those principles and those predictions can be evaluated. If they are true, then the obtained results support the validity of that conceptual scheme or explanation; if the predictions fail, then it is obligatory that the principles are adjusted until the predictions are successful in every case, and the direction of that change is clear.

Alternatively stated, a principled scientific approach is that approach that allows the system to identify the specific responsible element of the system that led to a failed prediction and that allows that element to be formally accepted as wrong and necessarily changed such that that failed prediction does not occur again. The systems raison d'etre is to make it impossible to make the same error twice.

The most logical practical and intelligent way to make correct predictions is formal explicit reasoning based on reliable empirical evidence. The most logical practical and intelligent way to make better and better predictions is to adjust the formal reasoning process based on the accuracy of the predictions. The inevitable result of this principled approach is better predictions until the system perfects the explanation.

This paradigmatic approach provides support for the validity of the principles because they are consistent with a wide range of phenomena across a wide range of situations. This approach also provides the rules whereby principles can be extended or generalized to new situations.

In sum a principled system has:

1. systematic, principled, public, accountable framework with which to organize results
2. systematic, principled, public, accountable rationale for decision, therefore, a principled cumulative transitive path to a solution
3. possible to isolate where incorrect decision went wrong and

therefore, enable systematic advancement in the future;
progress is inevitable.

B. Impact of Decisions by "Whim," "Guess," or "Intuition" (Eclecticism)

Eclectic decisions are unprincipled; they are made as if they are done by a lynch mob in the heat of the moment. The prediction is what the proponent feels like saying at the time. When encountering exactly the same problem in the future, the proposed prediction may be different. Additionally, when a prediction fails, the proponent simply changes to some other explanation, theory, or model. When encountering the initial situation over again at a later time the proponent is likely to invoke the failed explanation, theory, or model as if it had not been disproven. No transitive cumulating gain is possible with an eclectic approach.

Eclecticism is popular because without publicly available principles, no one can ever prove the theory behind the decision wrong in that there was no reason to predict one thing or the other. Additionally, if there is no reason to predict one thing over the other, then a proponent could try to argue that they could not be held accountable for having made a wrong choice.

The bad thing with the eclectic approach is that each practitioner must start from scratch and arrive at solutions as best they can because there is no algorithm which cumulates the knowledge of the field. The knowledge growth across generations is no better than that across generations of dogs. Systems that use this approach do not result in systematically cumulating knowledge and haven't had much progress since the dawn of humankind (for obvious reasons). There is little likelihood progress will speed up in the future.

In sum:

1. No systematic framework with which to organize results.
2. No systematic rationale for decision therefore no principled cumulating path to a best solution.
3. Impossible to isolate why incorrect decision occurred and therefore, no systematic advance is possible. Progress is unlikely.

X. Paradigms: The Optimizing Mechanism Underlying the Evolution of Our Understanding of What We Label Reality (i.e., Science)

A. Introduction and Overview

Thomas Kuhn provided a conceptualization with which it is relatively easy to understand how the various sciences function, how their various instantiations articulate, and how they evolve to better deal with nature.

At the core of his proposal is considering the similarities of a science and a game. His term for a particular worldview and set of rules of practice is a "paradigm." There is a goal to attain, rules specifying acceptable and unacceptable ways to attain that goal, and all the practitioners must "play by the rules" to be considered scientists practicing that science. Obviously there are multiple simultaneous games or paradigms in play. There can be both chemistry and psychology and even separate psychology paradigms such as cognitive or behavioral approaches.

In principle, a paradigm could be as local as one person's view or way of doing things on a particular day, to as global as an entire field's conceptualization of virtually everything for a millennium. Clearly, a meaningful paradigm involves many scientists over many years.

Paradigm change could be as minor as a simple adjustment in methodology (often labeled paradigm shift), to a total change in virtually every aspect of the paradigm (often labeled a paradigm revolution). Clearly, a meaningful paradigm change involves the change in many elements of the paradigm.

Physics could be seen historically as the entirety of a paradigm defined by Newtonian mechanics which evolved to a view which subsumed Newtonian physics as a special case of Einsteinian relativity. Historically, psychology could be seen as a paradigm based on internal mental conscious causation as exemplified by Tichner and Freud to radical behaviorism with a strict adherence to external empirical events and a focus on the effects of reinforcement.

Until a field has perfect and total knowledge, any element in the set of known things could be wrong. The dilemma is how to make actual progress toward perfect total knowledge even if the steps are increments from something that is not perfect to something else that is not perfect but is at least guaranteed to be better. The alternative is to have total chaos and no basis to choose one datum over another until some moment at some distant time in the future when perfect knowledge is available (how that perfect knowledge would come about, could be realized to be better, and could be proven; is a mystery).

The hill climbing metaphor makes clear several issues pertaining to paradigmatic progress by providing a very simple concrete example as a template:

1) the object is to get to the top of a hill. In science it is to attain perfect knowledge.

2) standing around nihilistically claiming that no solution strategy is perfect and therefore nothing can be done has one guaranteed result; no progress

3) subjectively deciding what direction is "better" without any empirical evidence is labeled the "drunkards walk" and make no progress either.

4) deciding what direction is "uphill" without any comparison to a base is labeled a "guess" and is not guaranteed to make any progress.

5) Stepping off in each possible direction and comparing each result to the base and then going to the best alternative will typically keep moving us "upward" until we reach our goal.

6) One failure of the hill climbing strategy is if we step onto a hillock on the side of the hill, we will meet the criterion of all directions are down without

actually reaching the summit. We would be trapped on the hillock. The instantiation in science of the hillock trap in the metaphor would be believing we had perfect knowledge when we did not.

The simple solutions and rationales that would be obvious in the hill climbing situation are mirrored in paradigmatic research.

a. In the total absence of any indication there is evidence of anything beyond the hillock then we are on the summit by definition. A hillock trap was possible but it did not occur.

b. If there is some empirical evidence of something beyond our current position, then the nature of that evidence is directly researched and compared to where we are currently which leads to its resolution. That activity is labeled "normal research" by Kuhn.

B. "The Structure of Scientific Revolutions"

Thomas Kuhn (1962) described the mechanism underlying the historical/social evolution of science in "The Structure of Scientific Revolutions." The following sections are excerpts from, or are rough summarizations of his chapters, and provide behavior analytic examples of his points. You really should read his short book.

1. Scientific History as Paradigms and Paradigm Change

From a big picture view, science is best characterized by long periods of stable frames of reference interrupted by periods of dramatic changes in perspectives. The history of science across centuries or millennia is rather like what happens as a person matures. Children have a paradigm that accepts that anything is possible. To them, they see a magician make coins vanish. Later, as an adult, as the result of more experience, the adult sees coins that could have done nothing but moved out of sight. The difference between children and adults can be seen as the difference between inadequate paradigms and adequate ones.

In the early days of psychology, people relied on an invisible internalistic conscious mind to explain behavior. In more modern times, the behavior analytic paradigm explains the behavior of organisms within an entirely externalistic paradigm that attributes learned behavior to the correlations of environmental events and functionally significant events (i.e., contingencies of reinforcement). This change in world views is similar to the change from gods and demons causing events in the environment such as lightening, tornados, pestilence, and earthquakes to the actual environmental causes such as static electricity and movements of the tectonic plates.

a. Conceptual Reminder: The Behavior Analytic Paradigm

i. Behavior analysis is a deterministic and principled science
ii. Behavior analysis is externalistic
iii. Behavior analysis establishes explanations, causes, and

meaning via the functional properties of objectively demonstrated entities

iv. Behavior analysis is concerned with understanding the moment-to-moment changes in an individual organism's semi-permanent adaptation to covariance in the environment that emerges and is lost across the seconds-to-days time scale

v. Behavior analysis is strongly focused on Thorndikian and Pavlovian conditioning

2. The Emergence of a Paradigm

Initially, an area of general interest has many researchers who are doing many different things, explaining things in many different ways. Eventually a group of interacting and cross validating people working on answering problems become interested in some questions and not others and become quite successful at explaining things with a principled set of processes. This result is a "paradigm" or the common view of a group of scientists.

The group comes to agree about:

1. what data are real
2. what explanations work
3. what questions will help understand or help extend the explanation and which will not

In the early days of psychology in the 1940s, 1950s, and 1960s, Skinner was the conceptual leader of the revolutionary codification of the worldview to which we now ascribe.

3. The Everyday Conduct of Science or Normal Science

Normal science is the practice of gaining knowledge by using some paradigm to construct the explanation. Finding unexplainable phenomena is not science; anyone can be capable of not explaining something. Brain damage helps enormously. The task of normal science is to extend the paradigm to new areas, and to develop technology consistent with the paradigmatic framework to accomplish that advancement. It uses facts considered fundamental and revealing to solve problems considered critical to the paradigm. Normal science articulates accepted explanations for accepted phenomena. Additionally, normal science is the finding of previously unpredicted phenomena and showing how those new phenomena <u>are</u> explainable with the existing paradigm. Note that this stage (normal science) typically lasts a very long time – often more than a lifetime.

A paradigm gains status because it handles problems that practitioners feel are important - not because it handles all problems. For example, the current scientific paradigm underlying archeology is based on the fact that humans built the pyramids. As a result, an investigation into whether ancient aliens from this galaxy or some other galaxy built the pyramids is not a meaningful analysis regardless of how much advertising the TV show sells. To not use the paradigm to explain something is to cease practicing the science it defines just as not following

the rules of baseball is to cease playing the game those rules define. To simply assert out of the blue that ancient aliens built the pyramids in the total absence of a single alien artifact and in the presence of many human artifacts used to build the pyramids and in the presence of written records of how the pyramids were built by humans is to cease practicing archeology.

The task of normal science is to explain current problems with explanations such that the majority of past and present findings are consistent. That is somewhat like a judge trying to be consistent with precedent. Another example is a serial novelette where each student adds ten pages to the story when it is their turn to carry on the storyline while maintaining coherence across segments. The new story must be consistent with all that went before.

Scientists take the foundation of their field for granted. From that point they push on to more abstract and recondite problems and increasingly they report their results in articles addressed to other specialists rather than in books addressed to the general public. Similarly, a conversation group at a party cannot make much headway if it is constantly explaining the beginning of the story as each newcomer joins in. Behavior analysis journals for the most part do not attempt to convince non-behavior analysts of the importance of their paradigm or how it works; that task is left to texts such as the present one. Most behavior analysts wish to use their time discovering why things happen (basic research) or how to solve problems (applied research and practitioners) not how to convince skeptics or educate students.

There are three related aspects of normal science or paradigmatic research.

1. First the task of normal science is to show how the paradigm explains the phenomena not how some event is entirely new and inconsistent with all that went before. For example, The task of research into a disappearing coin of a magician is to show how the disappearance was accomplished by a sight of hand. This only makes sense if the paradigm is the synthesis of all we know about nature and has the most broadly based support and is the best proven explanation then it is far and away the most likely to be the correct explanation. Not only is this approach the most logical, it has been the most successful approach throughout history.
2. Secondly, the task is to solve challenging problems within a strong network of. rules or commitment to conceptual, theoretical, instrumental, and methodological positions.

    a. No element of the paradigm can be ignored. Just as a cake with the flour left out will be a failure.

    b. No contradictory element can be added just as a long dead fish added to a cake mix will result in a failure.
3. The meaning of the result of paradigmatic research is tied to the paradigm. For example, if an explanation for behavior that is correctly timed is based on the notion of an internal clock, then to a behavior analysis paradigm, the explanation has no meaning because an internal clock does not characterize anything that could be independently measured. Additionally, the event measured in one paradigm could be meaningless in another one. A touchdown in football is important, but meaningless in tennis.
4. Why follow the rules?

It takes only a few moments to realize the vast majority of our behavior is within the boundary specified by "the rules." We don't utter random sounds, rather we say sentences following the rules of language. We don't drive a car and start and stop and turn randomly. With a few more moments of thought, we can categorize rules into sets of "wiggle room" like "don't put broken glass. in your eye, don't leave egg salad out for 3 days, don't wear white after labor day, don't cut the red wire when diffusing a bomb. As a result, failing to follow the rules of a paradigm. have different outcomes depending on the rule and who is evaluating your behavior. Most readers will fault you if you explain something by invoking the space aliens but only a competent reviewer will note your failure to use the correct ANOVA design for a randomized blocks design with repeated measures on one axis. Simply put, you will have to know and follow the rules better than anyone (including yourself) who will be evaluating your research.

a. The Priority of Paradigms

A paradigm modifies how we view things much as our perspective governs what aspects of our experience we focus on. Much as behavior analysts “taking home” the ontogenically-established behavior as a function of reinforcement; or a biologist “taking home” phylogenically-developed behavior as a function of evolution. Alternatively, how a behavior analysist sees behavior in terms of the environmental events (the touch of the single neuron organism versus the neural activity of the single neuron organism by the biologist). A paradigm is a frame of reference within which nature is viewed; it is a perspective governing and making sense of what we observe.

Behavior analysts had presumed that an as yet unknown conditioning history was the cause of inexplicable cases of drug overdoses in novel situations. A hypothesis that was consistent with well-established behavior analytic principles was that the overdoses were simply the result of the absence of the suppression of the drug effect by the environmental cues that had been conditioned by frequent drug use in their presence. Research proved this specific analysis correct. Similarly, behavior analysts are now investigating how obesity may actually be the result of some as yet unknown conditioning history (e.g., Shangri la diet).

b. Normal Science as Puzzle Solving

The task of science is not simply coming up with a story about how something could have happened even if it is totally contradictory with some previous story used to explain something else. It should be self evident that little cumulative progress in understanding nature could result. Rather normal science is like puzzle solving. It starts with the solid bricks and stones of well proven facts and processes and figures out how what has been already proven could account for the new phenomenon. Offering a story made up for the problem out of the straw and grass of opinions and possibilities is seen as fantasy. Scientists diligently work to prove themselves expert puzzle solvers by showing how the new is just more of the old.

c. Dilemma of Necessity to Advance Our Knowledge Base But Even Greater Necessity to Resist Mistakes or Getting Side-tracked

Normal science must continually strive to bring theory and observations into closer agreement. Failure to achieve a solution discredits only the scientist not the paradigm. Failures to explain occur when the paradigm is overextended beyond the facts or into areas without precedent and that have not yet been conceptualized. But to be useful, paradigms must be assumed to work when extended beyond the present facts.

Ptolemy's followers saw errors of prediction as simply something to resolve within the Ptolemaic paradigm because the paradigm was assumed to be correct. Copernicus saw the errors of prediction of the Ptolemaic paradigm as a disproof of that paradigm. However, if all members of a community responded to each anomaly as a source of crisis or embraced each new theory advanced by a colleague, science would cease. It is for that reason that any disproof of the paradigm by researchers are automatically discredited and the researcher is seen as inadequate to the task. As luck would have it for Copernicus, his jumping ship was one of the rare examples of paradigmatic revolution being the right thing to do.

Returning to the marriage example, the complex balance between sticking with the old and jumping ship can be appreciated. First, imagine if marriage really were to the death no matter what, but on the other hand imagine if everyone who got married began shopping for a better spouse the next morning.

While Skinner had initially articulated his paradigmatic views in the latter portion of the 1930s, behavior analysis with its rejection of internal explanations did not come to dominate psychology until more than half a century later.

4. Paradigmatic Failure and the Emergence of Scientific Revolutions

Sooner or later the existing paradigm or model begins to strain. Even people accepted as being the best practitioners of the paradigm begin to have difficulty accounting for all the data with the paradigm. Generally, a problem considered important, well documented factually, and consensually valid but at the same time anomalous, resists a paradigmatic explanation. This leads to the formulation of primitive explanatory systems not strictly consistent with the paradigm. Eventually these explanatory systems become incompatible with the accepted paradigm and in some cases, eventually supplant the old paradigm.

It is difficult to forecast what the future will have in store for behavior analysis. The history of mainstream psychology provides a good illustration of paradigm revolution. Hull's model was adjusted several times to account for findings that were inconsistent with his model. Need reduction became drive reduction and subsequently, drive stimulus reduction. Each system became more complex and cumbersome. Eventually, the only solution was to change the paradigmatic rules by focusing only on externalisms, as Skinner did with radical behaviorism.

5. Paradigmatic Revolution as a Fundamental Change to an incommensurably Different Worldview

Led by revolution scientists adopt new instruments, look in new places, more importantly they see new and different things when using familiar instruments in places they looked before.

When humans first looked at the stars at night, they saw lights hanging down from a great firmament or dome like an upside-down bowl. Some lights did not remain constant with respect to the other lights; they moved - they wandered. They were called wandering stars. Later the night sky was seen as a vast space in which stars resided and through which planets moved. Those movements were seen as orbits or the path taken by an object around the central object in the solar system. The concept of space, the solar system, and an orbit was created by the paradigm that conceptualized the sky and the movements of the planets that way. The point being that what was once seen as an upside-down bowl over an anchored flat earth became a vast empty space within which the earth itself floated. The interesting fact is that no one has ever seen the solar system and the 8 rotating planets from a distance like illustrations of the entire solar system.

The difference between mixtures and compounds provides another example of a change in worldviews caused by a paradigm revolution and is illustrated in Figure 2.11. Before chemistry, alchemists mixed things together – salt and water, salt and pepper, and hydrogen and oxygen and they were all seen as mixtures. Dalton had a different paradigmatic conceptualization – to him salt and water and salt and pepper were mixtures or solutions, while hydrogen and oxygen combined in a completely different way (i.e. atomically). He saw these latter combinations as chemical combinations. They always combined with fixed proportions. Dalton's revolutionary view was that solutions and compounds were different and required different theoretical consideration. With that realization, he changed alchemy to chemistry.

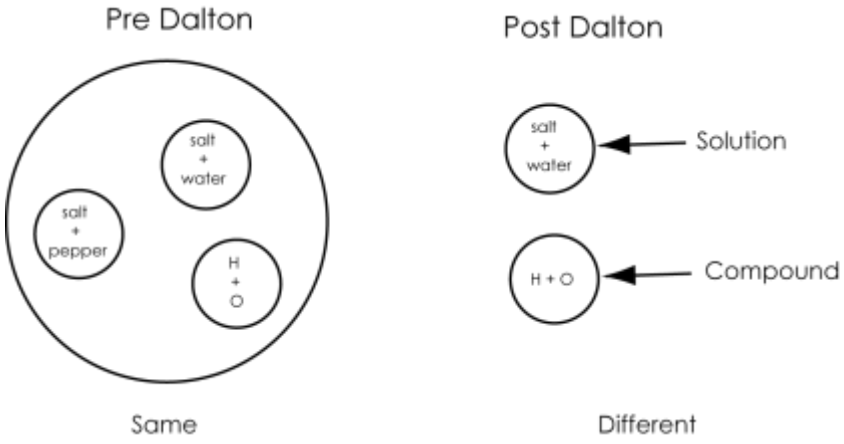

Figure 2.11 Before Dalton, salt and water, salt and pepper, and hydrogen and oxygen were considered the same type of combinations. After Dalton, salt and water, and hydrogen and oxygen were considered totally different ways that things can combine.

For Dalton, if the mixture did not have a fixed proportion, it *ipso facto* was only

a mixture and could not be a compound - **so any proof of a counter example to his theory was just interpreted as a mixture**. If a "compound" acted like a mixture, then it was no longer considered a compound but was defined as a mixture. His conceptualization was one of the most important paradigmatic advances in the history of chemistry. After Dalton, chemistry became the study of compounds and the rules of their combination.

In the same way that modern chemistry sees all matter as compounds of more basic elements, modern behavior analysts see all behavior as the control of behavior by stimuli. In the same way that modern chemistry is the study of the conditions under which compounds are formed, modern behavior analysis (psychology) is the study of conditions that come to control behavior, rather than how the mind comes to understand nature and then behaves accordingly.

For example, a cognitive introductory psychology text will typically present Skinner's work as "a pigeon learning that it must peck the key to get food." Thus, describing Skinner's procedure from a cognitive paradigmatic perspective and completely missing Skinner's whole point. **From a behavior analytic paradigm, research is focused on how outcomes alter the probability of the preceding behavior. The organism is not part of the equation.**

A behavior analytic explanation specifies that any short time scale organismic adaptation in any species is a function of reinforcement and is focused exclusively on the behavior change as a function of environmental contingencies. It considers what the organism learns or thinks as irrelevant, because it is a derivative phenomenon and a tautology. Radical behaviorism is understanding how to predict and control behavior with environmental stimuli NOT why a pigeon pecks.

These types of fundamental errors occur because the proponents of competing paradigms practice their trades in different worlds.

6. Summary

The following sections summarize Kuhn's major points.

a. What is a Paradigm?

A paradigm specifies what data are real, the fundamental processes or principles driving the natural world, the principles by which everything within the paradigm is understood and explained, and the procedures that are accepted as providing the proof. The paradigm is the frame of reference: the rules and facts of the game. Paradigmatic progress occurs by showing how the current paradigm explains any phenomena originally thought to be inconsistent with the paradigm.

b. Both Normal Science and Paradigm Revolution Can Be Seen as "Hill Climbing" Based on the Most Valid Information Available

i. Normal Science or Within Paradigm Hill Climbing

(1) A base of knowledge and processes is accepted

2) Comparisons are made between the existing base and new information. Normal science specifies the accepted boundaries of the information and what new phenomena are acceptable challenges.

(3) When a more comprehensive solution than the current understanding is available and it is within the paradigmatic framework, it is accepted as the new knowledge base.

ii. Paradigmatic Revolution or Between Paradigm Hill Climbing

(1) A base of knowledge and processes is accepted

(2) Occasionally, a finding stubbornly resists being well explained with the existing paradigm.

(3) When a better paradigm is available that explains more phenomena better and more coherently, it becomes the new paradigm.

c. A Paradigm Supports the Validity of its Principles and Provides the Ability to Extend Those Principles into New Situations

i. Because a paradigm is a very large set of findings all interlinked by the same fundamental processes with virtually no inconsistencies, then all that data can be said to provide multiple converging evidence for all elements of the paradigm.

ii. Because a paradigm is a set of formalized principles that specify why things are happening the way they do it also provides the understanding which enables the extension of the principles to new situations (generalization of the functional relationship) by allowing the new situation to be seen as a special case of the old situation.

iii. Because of its formal nature, a paradigm makes predictions about what will happen in all possible situations and why. Any failures to predict provide the information to self-correct the predictions by reconceptualizing how the paradigm could explain the observations.

d. Why is the Existing Paradigm Always Presumed to be Correct?

Our existing body of scientific knowledge and its principles of action have been proven to be the best available based on the widest possible set of facts and is therefore treated as veridical. That approach has been shown to be the most productive in advancing science. It has been extremely rare when a new potential paradigm provided a net gain from the established paradigm.

The burden of proof is on any alternative view because:

i. The current paradigm has been proven to provide the best explanation for the widest variety of observations.
ii. The chance of an alternate paradigm providing a better explanation is very small because all other known paradigms have already been proven inferior.
iii. Scientists are more interested in making progress than evaluating alternatives that are virtually all useless. It's rather like being on the way to a four-star restaurant and someone says: I have an idea, let's stop at that unknown diner instead, it might have better food.
iv. We cannot make progress if every time a discrepancy occurs, we presume that our world view is wrong and we start again along some new path (see item iii).
v. We cannot sit back and believe in nothing until perfect knowledge is given to us.
vi. Knowledge generation requires so many people doing so much research for so long, that unless it has a common paradigm, it cannot cumulate.
vii. Failure in a paradigm is the only way to find out what particular solution is actually needed to make the paradigm better.

Each individual researcher is of course able to choose whichever path they want, but the scientific community is also permitted to optimize the productivity of their group as a whole, and take that rogue researcher's work seriously or ignore it. The history of science clearly supports normal science as the most likely to be productive and attempted paradigm revolution to be an error. When a researcher declares that their research is the beginning of a "new paradigm" it means that they couldn't understand the determinants of their results. It is saying "I couldn't understand why my results happened so I'm making up a new rule to explain them. It would be like a fisherman catching a fish shorter than the legal limit and drawing a new ruler on a piece of paper showing that the fish was long enough. The new ruler would not fool a game warden, a new paradigm does not fool a properly trained scientist. It's ironic that Kuhn's conceptualization which is intended to emphasize how an explanatory system staying the same is the source of its explanatory power and validity is used as the label for making up an ad hoc pseudo explanation.

In review, because our paradigm is based on everything we know, our paradigm is consistent with everything we experience, and our paradigm is our

most valid and reliable explanation of everything, we accept our paradigm as "reality."

e. A Paradigm's Description of Reality Must in Some Ways Be Considered as More Fundamental Than Direct Experience

i. How we must interpret our sense data is with respect to what is most likely, or most consistent with everything that is known. A disappearing coin in the hands of a magician must be seen as a not yet understood slight-of-hand trick because that assertion has multiple converging evidence and consensual validation. It is the best choice available. Choosing "magic" as the explanation has never worked in the past.

ii. This view suggests that the naively perceived natural world (e.g., your eyes "saw" the coin disappear) is not the final arbiter of reality. But that view does not imply that the postulation of invisible causes (e.g., "an invisible gorilla stole your money) is a legal explanation. Our paradigm does not allow the self-serving postulation of invisible thieves. The paradigm requires consensual validation and a systematic, consistent framework.

iii. Cosmology is currently in just such a dilemma. The paradigm specifies how the cosmos must function, but it does not work as predicted. Many cosmologists felt it necessary to postulate an invisible type of matter and an invisible force to salvage the paradigm. Others felt that the data justify a second look at the details of the mathematical model or the paradigm itself.

CHAPTER 3

Scientific Method

I. Exclusive Focus on Objectively Provable Entities

II. Systematic or Principled Explanations, Theories, and Models

III. Logical Foundation for the Procedure Used to Establish Causation Without Confounds

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B. Two basic strategies of research design
   1. null hypothesis significance testing NHST: “groups design”
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1. commonalities in behavior analytic research and traditional NHST
2. differences between NHST and behavior analytic research
   a. weaknesses of NHST which are not irreconcilably different than behavior analytic decisions
   b. serious inadequacies in NHST
      i. conceptual precursor: determination of a change in the dependent variable caused by the independent variable
         (a) detecting an effect in single subject designs
         (b) detecting an effect in groups designs
      ii. single subject designs have better detectability than group designs
      iii. reliability in NHST designs actually refers to the likelihood that the group average will show the effect again not that each individual will show the effect again
      iv. generality in NHST designs is based on unprincipled and unsystematic intuition
      v. NHST designs squander research effort
      vi. the behavior of an individual is not necessarily well predicted by a group average

VII. Optimizing the Subject, Apparatus, and Procedure for the Purposes of the Research

A. Optimized or apt subjects
B. Optimized or apt apparatus
C. Optimized or apt procedure

CHAPTER 3

Scientific Method

I. Exclusive Focus on Objectively Provable Entities

Recall the discussion in Chapter 1 concerning the requisites of science. All elements must be empirical, reliable, consensually validated, have multiple converging evidence, be consistent with the scientific paradigm, and have operation/functional definitions. The elements and their functional relationships must be understood or must provide for adequate description, prediction, control, synthesis, and explanation.

None of these properties would be possible unless all observations were objective (i.e., all observers describe the events with the same properties) if there is a discrepancy between observers then that discrepancy must be resolved. An important way to assure that all observations are objective is to require that all observations be empirical or described and defined in terms of the sense data people have in common.

This chapter provides an overview of the procedures used in scientific research, why those procedures are what they are, and why some procedures are better than others.

II. Systematic or Principled Explanations, Theories, and Models

A systematic or principled explanation, theory, or model has logical chains of formal reasoning that begin with objective events and processes considered relevant and the proposed fundamental functional relationships. The ensuing formal Euclidean- like reasoning can explain all known behavior and functional relationships exhibited by the organisms, makes no contradictory predictions, and correctly predicts functional relationships not yet in the database. Better explanations, theories, or models are simpler, have less ambiguity, and have explicit, objectively measurable predictions. Adjustments to the principles are obligatory when there is a failure to correctly predict. Systematic and principled explanations are easily implemented as a computer program because no wiggle room, fudge factors, or subjectivism is permissible. A simple example of a principled system is an AI medical diagnosing system.

III. Logical Foundation for the Procedure Used to Establish Causation Without Confounds

The present issue is how to identify the cause, the whole cause, and nothing but the cause of an effect. It must be remembered, that any candidate is not necessarily the true cause, and you are in search of the true cause. An experiment is a method of exposing and understanding the true cause of an effect.

Unfortunately, you will rarely be in a situation where you see nothing but the relationship between some very specific isolated causal input and some very specific isolated behavioral output. Organisms are always receiving many inputs, any of which could affect the output and always have a long history of interacting with the environment. In addition, organisms are always exhibiting many behaviors, they never do only one isolated thing. Your task of finding a single cause and a single effect out of the millions of events and millions of behaviors emanating from your subject would appear daunting.

Luckily, an approach is available which isolates just the input and output factors in which you are interested. This approach, labeled "the method of differences" is based on the realization that a comparison with an untreated control condition removes from consideration all factors that are the same and leaves only those factors that are different between the control and treatment as potential causes. Simply put, the difference in what is done to a subject (or group) under two conditions is the cause of the difference in what the subject (or group) does under those two conditions (if it is not caused by chance).

It is remarkable how precisely and easily the cause of an effect can be correctly identified. An example of this type of procedure is the determination of the specific object in a room that is causing an allergic reaction. Various objects would be removed from the room until the allergic reaction subsided. In order to assure that the cessation of sneezing was not a coincident, objects would be returned until the reaction returned. By repeatedly removing and returning various items or parts of items, the specific object(s) causing the reaction would eventually be identified as the true cause and not a coincidence even if it were a small patch of pollen on a throw rug. The reinstatement of the effect is necessary. Unless it is done, a controlling or causal relationship between the two events could be a coincidence, and the true cause would not have been demonstrated.

A. An Analytical Balance Metaphor for the Method of Differences

Suppose that you want to measure the effect of the caffeine in coffee without measuring the effect of any of the other chemicals consumed by drinking the coffee itself. On the surface, this seems like an insoluble problem. A metaphor can be used to provide a simplistic concrete example of the method of differences using the weight of caffeine in coffee as a metaphor for its behavioral effects. The apt metaphor for this task is trying to weigh the caffeine in a cup of coffee without weighing the coffee itself. This metaphor is illustrated in Figure 3.1.

Let's suppose caffeine alone cannot be put on a scale because it cannot exist

when isolated from coffee. To measure the weight of caffeine, you must have the caffeine in coffee. The weight of coffee itself is an unwanted but unavoidable aspect of weighing caffeine. The coffee is a confound in that you only want to know the weight of the caffeine and you don't want the weight of the caffeine to be influenced by the weight of the coffee. Amazingly enough you can, in fact, weigh just the caffeine in coffee by canceling the weight of the coffee. If you place coffee with caffeine on the right pan of a balance then place an exactly equivalent amount of coffee without the caffeine on the left pan of the balance, it has the effect of removing the weight of the coffee from the weight of the caffeine in the right pan. Only the difference between the two pans (i.e., caffeine) affects the weight indicator.

Similarly, if you wish to measure the behavioral effect of caffeine without the coffee, then you give a person decaffeinated coffee on some days and caffeinated coffee on other days. In that way, the difference in the treatments (i.e., caffeine) will be isolated and only the caffeine effects will be measured as the difference between the behavior resulting from coffee plus caffeine and the behavior resulting from coffee without caffeine.

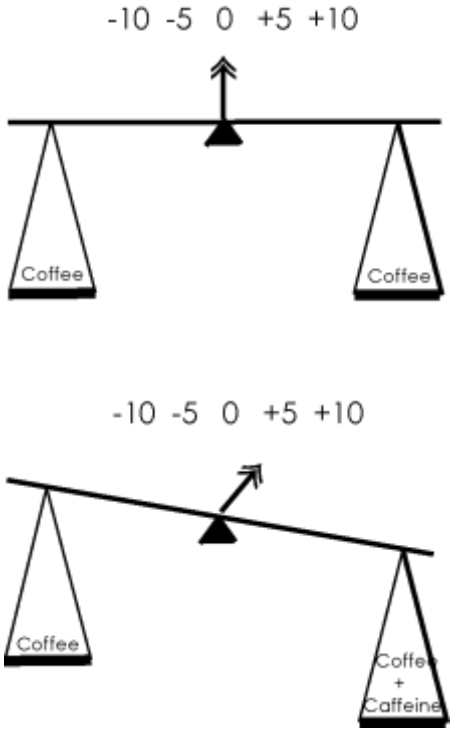

Figure 3.1 An analytical balance metaphor for the method of differences. The upper portion illustrates that when the two pans have the same contents, the result is that the arrow shows no difference. The lower portion shows that only the difference in what is in the pans can account for the difference in the needle because when the same things are in both pans, the result is no difference in the needle.

An experiment can be seen as doing whatever is necessary to arrange exactly identical conditions in each condition except for the independent variable (e.g., the

caffeine), so that any difference in the dependent variable (e.g., tremor rate) is caused by the independent variable. Any difference between the two experimental conditions in addition to the independent variable (e.g., cream in one of the cups) is a confound and is an error.

In sum, the difference in the pointer is caused by the difference in the pans (or chance), just as the difference in the behavior is caused by the difference in what happens to the subject (or chance).

B. An Algebraic Metaphor for the Method of Differences

The following simplified semi algebraic analogy illustrates the method of differences in a fourth way. Suppose the nearly infinite number of possible stimuli (inputs) in a crowded cafeteria is represented as:

A + B + C + D + E . . . .

Figure 3.2 The letters represent the many stimuli in the cafeteria.

(these are the contents of one pan in Figure 3.1). The nearly infinite variety of behavior (outputs) in that cafeteria is represented as:

V + W + X + Y + Z . . . .

Figure 3.3 The letters represent the many behaviors in the cafeteria.

(this is the deviation of the pointer from the center of the scale in Figure 3.1). The fact that the general behavior that is occurring can be roughly attributed in some way to the general situation can be depicted, therefore, by,

A + B + C + D + E . . . . ----------> V + W + X + Y + Z . . . .

Figure 3.4 The letters on the left could be seen as causing the behaviors on the right.

Now suppose that you are in the cafeteria and see a very attractive potential date sitting a few tables away. You add a smile and a nod to the mass of stimuli in the cafeteria.

A + B + C + D + E . . . . + P ----------> V + W + X + Y + Z . . . .

Figure 3.5 The P represents a stimulus you could add to the stimuli in the cafeteria

Much to your satisfaction, the total behavioral picture in the room changes to include a wave by that person.

A + B + C + D + E . . . . + P ----------> V + W + X + Y + Z . . . . + S

Figure 3.6 The S represents a behavior in the cafeteria that followed the stimulus that you added.

A, B, C, D, E, and P can be seen as the causes for V, W, X, Y, Z, and S. However, we are actually interested in only a subset of all possible causes (i.e., only your smile and nod) and are interested in only a subset of all possible outputs (i.e., the wave). We don't really care about the smell of hamburgers or the clank of dishes. Nor do we care about all possible dependent variables (e.g., people moving around and talking).

You can apply a bit of reasoning and find that you can cancel all the stimulus factors that were the same before, during, and after your additional stimulus as being extremely unlikely candidates for causing the change in the mass of behavior in the cafeteria. The smell of hamburgers and the clanking of dishes occurred before, during, and after your smile. Additionally, you could cancel all the behaviors occurring in the cafeteria that were the same before, during, and after your smile and the subsequent wave. It would appear your additional stimulus and the subsequent wave are the only events remaining after all the potential "causes" and "results" that were the same canceled. It is as if you could algebraically subtract the before from the after.

A + B + C + D + E . . . . + P ----------> V + W + X + Y + Z . . . . + S

A + B + C + D + E . . . . ----------> V + W + X + Y + Z . . . .

/ / / / / + P ----------> / / / / / + S

Figure 3.7 The difference in the behaviors occurring in the cafeteria (i.e., S) could be seen to have been caused by the difference in the events happening in the cafeteria (i.e., P) if it is not simply chance.

We can extend this cafeteria metaphor to illustrate confounds in an experiment. It violates the spirit of the simplistic metaphor a bit, but the more complex version of the story is in fact more accurate than the earlier version of the cafeteria example because you may find that you could have made an error in assuming too much. If all conditions were not the same, all factors did not cancel out.

For example, someone else behind you could have also been smiling and waving (we have all seen that cliché in a movie). You would then be left uncertain as to exactly what caused the wave. The wave could be for you or it might be for the other person. Note that it is not the case that you know that the wave was for the other person - you only know that it could have been for you or it could have been for the other person.

(after) A + B + C + D + E . . . . + PQ ----------> V + W + X + Y + Z . . . . + S

(before) A + B + C + D + E . . . . ----------> V + W + X + Y + Z . . . .

/ / / / / + PQ ----------> / / / / / + S

Figure 3.8 If more than one difference occurred in the cafeteria, then the difference in the resulting

behavior could have been caused by any or all of the things that were different or chance.

Your independent variable (P) is guaranteed to cause the change in the dependent variable, (S), only if all factors cancel and are, therefore, proven irrelevant. Anything that changed and was not corrected for (i.e., Q or P and Q) may possibly be the actual cause and lead to the possibility of alternative explanations for the obtained result.

Remember that the whole purpose of an experiment is to reduce or eliminate alternative explanations for what you are demonstrating. If you allow potentially relevant variables to fluctuate in an uncontrolled fashion you cannot be sure what caused the effect. Was it the result of the change that you deliberately added or was the effect the result of the other simultaneous and therefore confounded changes? You are left with very little that you can say with confidence.

The solutions for the simplistic cafeteria example are many. One would be to stand with no one else behind you and assure yourself that nothing other than your smile was changed at the same time that you smile. Alternatively, you could have the other person smile while you were not smiling and thus would be able to subtract that condition from the condition in which you smile. If there is no response when the other person smiles, but there is a wave when you smile, then you have some reason to believe that that the wave was for you. Alternatively, you could smile from three different locations to see if the wave response occurs to your smile from each location. It is a tangent to the purpose of this example but insightful experimental design is illustrated by realizing that you could walk over to the person and say, "I don't know if you were waving in response to my smile, but I have always wanted to meet you …"

As a fifth example, an individual could be given a pill on many occasions. On a random half of those occasions the pill could contain a drug (treatment) and on the other half the pill could contain nothing (baseline).

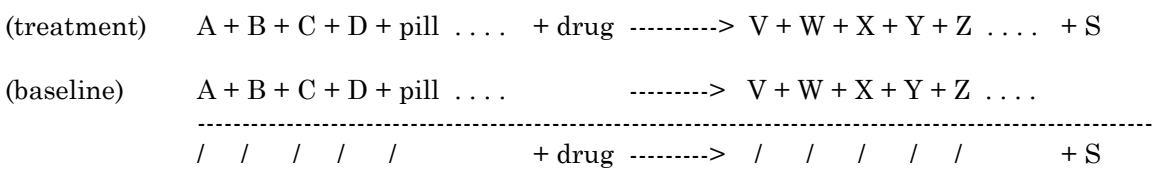

Figure 3.9 If the drug is the only difference between the antecedent events in the two conditions then only the drug could have been the cause for the difference in what subsequently occurred, if the effect was not simply chance.

In this case "drug" represents the independent variable; S represents the dependent variable (possibly better health); A + B + C + D + pill ---- represents contextual, constant variables; and V, W, X, Y, and Z are the behaviors during the baseline that cancel out the common behaviors during the treatment (possibly breathing, eating, etc.). Any variable that you want to eliminate as a potential cause should be eliminated by making it the same in the baseline and during the treatment. It will therefore be canceled out.

To accurately assess a functional relationship, you must make absolutely

certain that the confounding influences have been removed. For example, the person knowing when the drug is present because of its very strong taste. Your major adversary in the quest for truth is the uncontrolled variable. If uncontrolled variables could have been present you will not know for sure what, if any, effect the independent variables had had.

C. Summary of the Method of Differences

In sum, the difference in what you do (or chance) causes the difference in what you get. In order to find out the effect of some factor, provide all but that factor during some other condition. Alternatively, start removing potential causal factors until the effect ceases, then add that factor or parts of that factor back in to assure yourself and your reader that that last variable was the active ingredient because the effect returns.

IV. Logical Foundation for Willingness to Reject Chance as the Cause of the Effect

The first task of an experiment is to remove all but the treatment from the list of potential causes. The method of differences accomplishes that task very efficiently. The second task of an experiment is to assure that the change in the dependent variable was actually caused by the treatment and was not simply the result of chance. In the previous examples maybe the attractive potential date was simply smiling because it was a nice day or the child learned to walk on its own.

The logic for removing chance as a potential cause of the change in the dependent variable is very simple. If an effect is very unlikely to be chance, then we can assume that it is not caused by chance and we will be very unlikely to be wrong if we claim that the treatment caused the change. In point of fact, we will be wrong in our assumption with the same likelihood that the effect is caused by chance.

A change in the dependent variable that is extremely unlikely by chance is considered a large treatment effect while a change in the dependent variable which occurs on its own every so often anyhow is considered a small treatment effect.

For example, if someone claimed to be able to influence how a coin flip came out and they made a fair coin land heads 100,000 times out of 100,000 then that would be considered a large treatment effect and we would be willing to accept the claim that they had caused the effect with very little possibility that the effect was caused by chance.

But, precisely when would enough be enough to prove that they could do it - after 1 out of 1 head, after 2 out of 2, after 5 out of 5, after 100 out of 100?; at what point does the number of heads become enough - 100, 1000, 943160?

As a first step, it is often accepted that if an event occurs five or fewer times per 100 by chance, we can act as if it did not occur by chance. In general, behavior analysis requires a more extreme albeit informal criterion. It is often said that until your theoretical opponent accepts the result, you haven't done enough to prove it non-chance.

The top portion of Figure 3.10 depicts the frequency of each number of heads when 100 coins are tossed. There are many occurrences of 50 heads and very few occurrences of 100 heads. It is outside the point of this example but note that the occurrence of 0% heads is as unlikely as 100% heads. The middle portion of the figure depicts how often simple chance could explain an outcome of more than 50 heads when tossing 100 coins, for example, 50% of the times there will be more than 50 heads. The lower portion of the figure illustrates a typical criterion for declaring that a treatment worked. (probability by chance equals five times in a hundred or 5%.

It is absolutely essential to understand that an event more extreme than the criterion (such as only if it happens less than 5% of the time by chance) does not prove that that number of heads is not chance. After all, 5% of all chance occurrences are more extreme than the 5% criterion. Rather, the decision made is to act as if the event is a true effect rather than chance. In point of fact, with a 5% criterion, you are guaranteed to be wrong 5% of the times. if you were betting on the outcomes of tossing 100 coins, you would act as if your opponent cheated if they ever threw a number of heads that only occurred 5 times in 100 or less by chance even though you would be guaranteed to be falsely accusing them of cheating five times in 100 tosses.

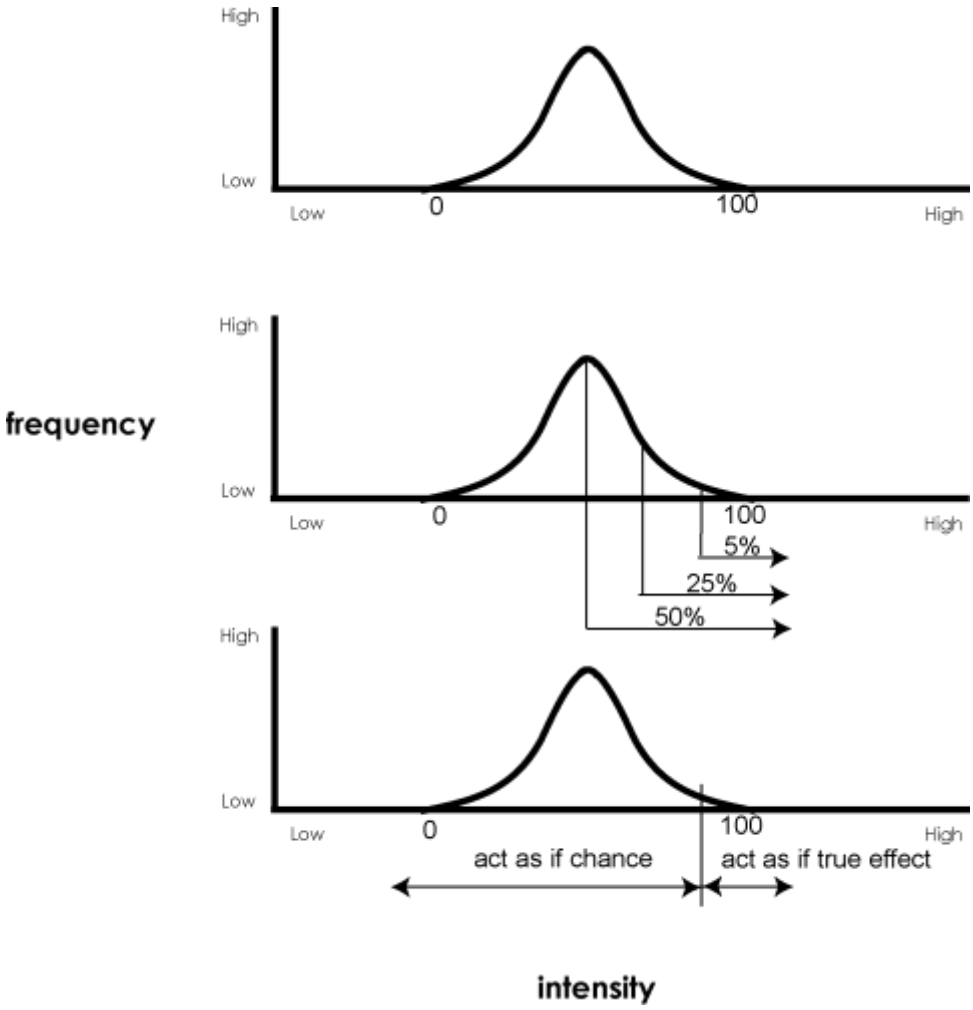

Figure 3.10 The upper portion of the figure depicts the number of heads that occur when 100 coins are tossed. The middle frame depicts the probability of the outcomes higher and more extreme than various cutoffs. The bottom figure illustrates a criterion for when to act to a higher event as if the event was a true effect as opposed to simply acting as if it were a chance outcome.

V. Logical Foundation for Optimizing the Cost/Benefit Ratio of Decisions to Reject Chance as the Cause of the Effect

Simply calculating how likely a particular event is out of a total (such as the criterion of acting as if it is non chance if the event occurs less than 5 times in a 100 by chance) is not the whole story. The cost of potential outcome errors must also be factored into any decision. In some situations making an error of presuming a true effect when it was actually chance could be catastrophic, while in other situations presuming that something just occurred by chance could be

catastrophic. Sometimes you care about jumping to false conclusions while at other times you care about being too cautious and not taking the needed action.

As a mundane example, suppose Charlie Chicken would be devastated by asking someone for a date only to be rejected. In order to minimize being turned down for a date, Charlie Chicken, may never ask anyone out regardless of the "vibes" that person gives off. That strategy reduces being rejected to zero, but also reduces the opportunity to have an enjoyable date to zero. Alternatively, in order to minimize the possibility of ever missing an opportunity to go out, Bob Bold may ask every girl in school (as well as total strangers at the mall) for a date, regardless of the "vibes" they give off, thus never missing a single opportunity, but at the cost of a lot of scathing rejections.

This simple story of two people with different personalities illustrates that the optimal decision as to when to ask for a date must be based on the cost of both a rejection and the cost of a missed opportunity. Each person and each situation may have a different cutoff ratio of rejections to missed opportunities and therefore a different criterion for how positive the vibes would need to be before they would ask for a date but nevertheless the point of when to ask for a date must be based on both costs as evaluated by each person.

This dating example can be conceptualized in a way that makes understanding the factors underlying the decision to ask for a date easy to understand. First, there is a decision or a choice of actions based on the strength of the "vibe," ask for a date or don't ask for a date; secondly, there are two outcomes: offer accepted or offer rejected. This 2 x 2 situation can be depicted in a choice of two actions by two outcomes contingency table.

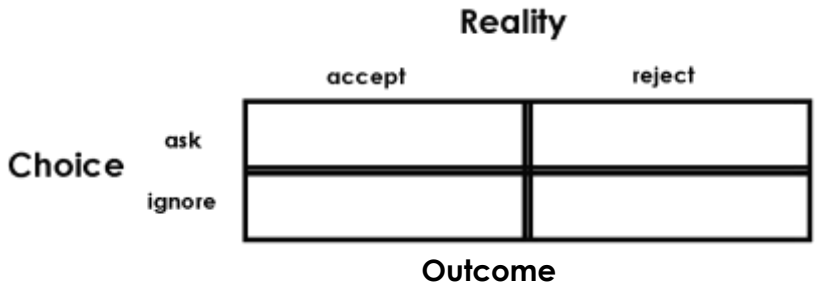

Figure 3.11 The events underlying every decision. There are two ways to be right and two ways to be wrong. Each can have its own cost or benefit.

For any and all decisions you cannot simply mindlessly decide whatever you feel like doing at the time. Common sense, as well as law, science and every other system rejects capricious decisions. The task is to separate a cause from chance but to also adjust the likelihood of each type of error such that the overall gain from the benefits minus the overall cost of the errors is maximized.

Decisions must be based on a weighing of both the cost of each of the two types of errors and the benefit of each of the two types of correct decisions; and then determining, based on the net value, the "criterion" (i.e., the point that is chosen for when enough is enough). This comprehensive approach to decision making in

an ambiguous situation is labeled the Theory of Signal Detection (TSD) and has become virtually the only way of separating chance from true effect. In the Bob Bold and Charlie Chicken example: if a rejection is terrible, then require a very strong vibe; if a missed opportunity is terrible, then ask for a date even when the person doesn't seem interested at all.

As an example situation requiring a decision where doing nothing when you should react is very bad is as follows: suppose you are camping out in very remote terrain and you hear a sound. What should you do? Go back to sleep or run for a tree? Placed in a TSD framework, it can be seen that one of two actual events could happen: the sound could be from something dangerous (a bear) or the sound could be from something insignificant (e.g., just the wind). You could behave in one of two ways: you could react to the sound by running, or you could ignore it. The figure below illustrates the four possible occurrences. Each correct decision has a benefit and each error has a cost.

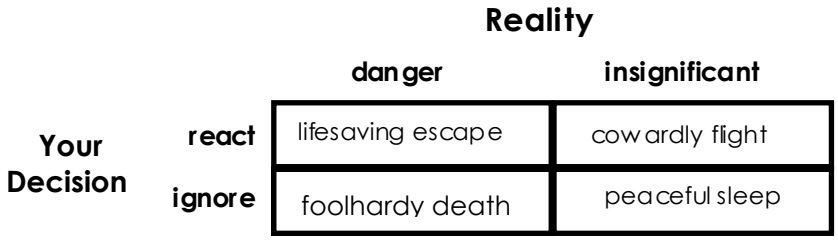

Figure 3.12 There are four outcomes to every decision: two ways to be right and two ways to be wrong. The values of all four must be considered to optimize a decision. In this case it is better to run for no reason (cowardly flight) than to be eaten by a bear (foolhardy death). The two types of errors are not equally bad; being killed is worse.

If you ignored the sound when nothing was there, you got a good night's sleep and were safe (peaceful sleep). If you ignored the sound when there was danger, you died (foolhardy death). If you reacted to the sound when there was nothing there, you spent the night up a tree for no reason (cowardly flight). If you reacted when there was danger, you saved your life (lifesaving escape).

Note that there is both a cost and a benefit to a decision to run and both a cost and a benefit to the decision to go back to sleep. If you react to the sound, you gain occasional lifesaving escape and pay occasional cowardly flight, if you ignore the sound you gain occasional peaceful sleep and occasionally pay foolhardy death. Each decision has the sum of the cost and benefit associated with it. If you're right, you get the gain, but if you're wrong, you pay the cost. For some decisions, the benefit far outweighs the cost, as it does in this running from a bear in the woods example. For example, many nights up a tree for no reason is a reasonable price to pay if you're not sure what made the sound.

A second example (Figure 3.13) and one with exactly the opposite payoff as the bear in the woods example (in this case doing something when you should do nothing is very bad), it is given by the mutual assured destruction (MAD) philosophy of an all-out nuclear counter strike option. This plan called for an all-out nuclear missile attack by the US against the Soviet Union if it was believed that the Soviets started to attack the US. Right or wrong, the entire planet would

be destroyed by radioactive fallout. The cost of a false alarm was the end of all life on earth for nothing. While this example sounds farfetched, it was a real policy supported by real people and almost happened when an artifact caused the American early warning radar to declare that an all-out attack had started. In this case deciding on a single all out nuclear attack is a bit excessive when you're not sure what is happening.

		Reality: Attacked	Reality: Not Attacked
Decision	Launch	Take them down with us	End of life on earth for no reason
	Wait	Conquered without a fight	Status quo

Figure 3.13 All four outcomes must be considered in every decision. In this case, erroneously believing that you have been attacked would end all life on earth and is much worse than the alternative error. The two types of errors are not equally bad, ending life on earth is worse.

Figure 3.14 provides the formal terminology used in T.S.D. The technical term for nothing but inconsequential events is labeled "noise" even when the background is random variations in light level or random variations in people's height. The technical term for a consequential event such as a change in the rate of cancer is a "signal." The signal occurs against the background and its value is therefore the sum of the signal and the background noise. It's therefore labeled signal + noise.

		Reality: noise + signal	Reality: noise
Decision	noise + signal	correct detection	false alarm
	noise	miss	correct rejection

Figure 3.14 The formal terms for the events underlying every decision and the terms for the four possible outcomes. There are two ways to be right and two ways to be wrong. Each can have its own cost or benefit. In Figure 3.12, misses were worse. In Figure 3.13, false alarms were worse.

All other things being equal, the two types of errors possible (false alarms and misses) are inversely related; they work like a "seesaw" (Figure 3.15). If you simply minimize misses, you maximize false alarms. If you simply minimize false alarms, you maximize misses.

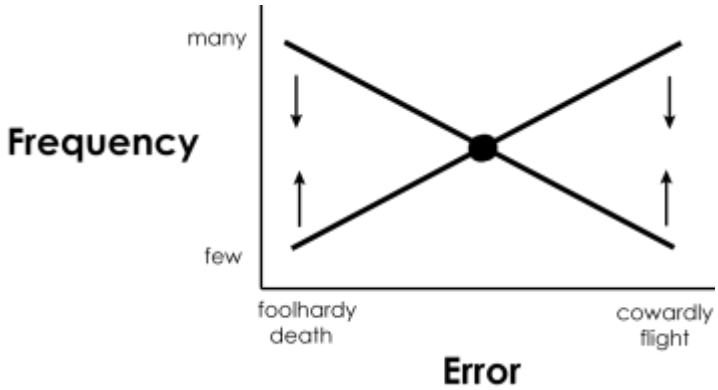

Figure 3.15 A "seesaw" representation of the inverse relationship between false alarms and misses. As misses are minimized, false alarms are maximized, and vice versa.

There are a number of additional points which do not change the major issues in T.S.D., but must be kept in mind:

- You don't know how many false alarms and misses you are making
- You don't know how many of each can occur when they are maximized
- You only know that as one decreases, the other increases.
- Just because an event that is very unlikely by chance occurs, it does not mean that your hypothesis (e.g., a bear) caused it. It could be a werewolf, rabbit, or someone coming to give you a million dollars.

Not all examples are one extreme or the other such as running from bears or not blowing up the world.

The necessity of putting substantial thought into the cost/benefit criterion is illustrated by a more "gray area" decision scenario. For example, an accused person could, in fact, be guilty or innocent and you as a juror could vote to convict or exonerate (Figure 3.16). Recall that each decision must be driven by the **net** cost benefit ratio of the outcomes of both of the two alternatives for both of the decisions.

	guilty	**innocent**
convict	guilty in jail	innocent in jail
exonerate	guilty on street	innocent live free

Figure 3.16 An illustration of the outcome matrix facing jurors in a court of law. The relative cost of the two types of errors (from a juror's perspective) biases the decision as to voting to convict or to exonerate, when all other things are precisely equal.

One type of juror may have a cost-benefit ratio that is more concerned with minimizing innocent people going to jail (false alarms) at the cost of increasing guilty people on the street (misses) and therefore may choose to have only a 1% or 0.1% or even .01% chance of making a false alarm (i.e., send an innocent person to jail). However, a different type of juror may have the opposite cost-benefit ratio and may not want much of a chance of letting a guilty person back on the street.

In sum, you must simultaneously consider the ratio of (the cost of many guilty on the street against the benefit of only a few innocents in jail) or (the cost of many innocents in jail against the benefit of only a few guilty on the street) and you must set your criterion for when enough of a signal is enough accordingly. For example, if false alarms (sending innocent people to jail) are very bad, then demand a very extreme result before voting to convict (e.g., beyond a shadow of a doubt). If misses (letting guilty people out on the street) are very bad then, have a very low criterion for when to vote to convict.

A. Graphical Example of Decision Analysis

The following figures in this section are all based on the camping example. Because concrete examples require concrete figures, these figures cannot simultaneously illustrate all possible situation. You will need to understand the essence of the camping example illustration and then imagine how the figure would change for other situations. Note that these issues are also covered in detail in chapter 12

First, the figures use Gaussian distributions to illustrate all distributions, in some situation the distribution may not be Gaussian. Second, the figures illustrate the signal plus noise distribution as higher than the noise alone distribution and positions that distribution at a specific distance from the noise distribution, in some situations those exact parameters may not be the case. Third, the criterion is given a specific value (distance from the mean of the noise distribution) In some situations that criterion may be inappropriate. Fourth, the position of the noise and signal plus noise distributions, their shape, and the criterions all control the ratio of the false alarms to misses. Other situations would control different ratios.

Figure 3.17 is the distribution of background noise (wind sounds). The upper portion of the figure depicts the intensity of the moment-to-moment noise over some time period (e.g., each minute). The bottom portion of the figure depicts the distribution of noise: a few very low amplitude sounds, and a few very high amplitude sounds but most sounds are in between.

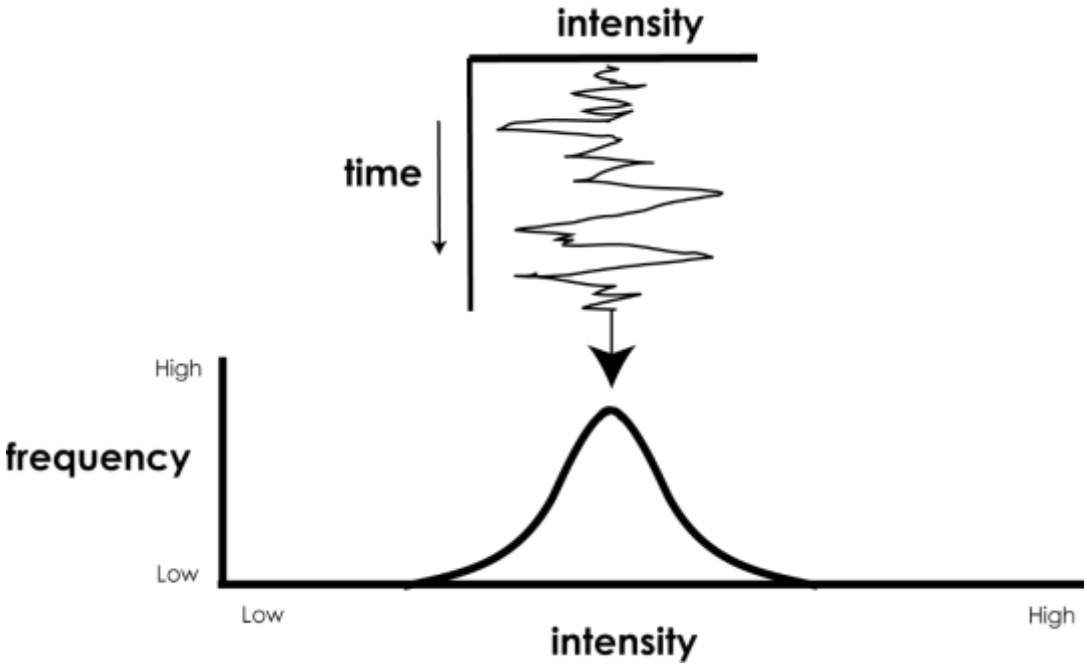

Figure 3.17 The upper portion of this figure represents the variations in the amplitude of background sounds (e.g., wind) over time. The bottom portion of the figure represents the frequency distribution of those background sounds (noise) across that time period.

Second, as illustrated in Figure 3.18, there is a distribution of signals which are the sounds made by a bear which are added onto the background noise (i.e., signal + noise). They could be centered anywhere and could be any shape but a concrete example must have a concrete figure. The distribution is drawn as a Gaussian distribution at a higher intensity than the background noises for simplicity.

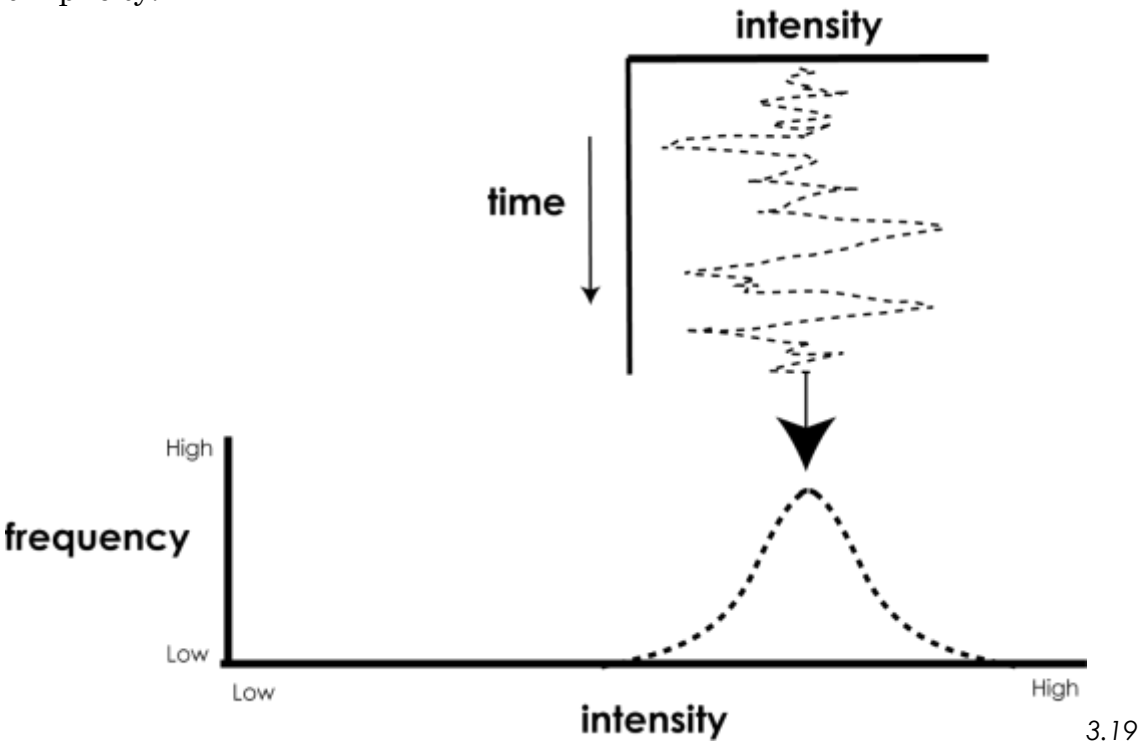

Figure 3.18 The upper portion of this figure represents the variations in the amplitude of sound when bear sounds are added to the background sounds over time. The bottom portion of the figure represents the frequency distribution of those dangerous sounds (signal plus noise) across that time period.

Two possible camping scenarios are illustrated in Figure 3.19; one illustrating signals louder than the background noise (the dotted function to the right of the noise distribution) and one illustrating signals that cause the background to become quieter (the dotted function to the left of the noise distribution). There is also a solid vertical line that indicates a possible criterion for what to do. Louder than this criterion, the decision is to act as if the sound is a bear (run in the camping example). Below this criterion the decision is to act as if the sound is simply the wind (sleep in the camping example).

Figure 3.19 The center distribution depicts the distribution of baseline or background sounds (noise) as shown in Figure 3.17. The two outer distributions represent two of the possible distributions of non-background sounds (signal plus noise) as illustrated in Figure 3.18.

Figure 3.19 is a reminder that the signal distribution could be anywhere: far to the left, far to the right, or even right on top of the baseline noise distribution. Try to keep in mind that the signal distribution could be anywhere from the extreme left to the extreme right of the noise distribution. You could imagine the signal during which the background noise goes quiet as being a tiger prowling the woods which makes all the other animals go silent) inclusion of this possibility in every example would require that every discussion of a very loud sound would also have a discussion of a very quiet period. You will simply have to consider that on your own while thinking these issues through.

Figure 3.20 A modified presentation of Figure 3.15. A seesaw representation of the relationship between false alarms and misses. As misses are minimized, false alarms rise.

Figure 3.20 shows a diagonal line. Presume that it pivots at the center like a seesaw. The right end of the see saw represents false alarms and the left end represents misses. The *y*-axis or height represents frequencies: lower positions represent lower frequencies, and higher positions represent higher frequencies.

The diagonal line illustrates the inverse relationship of the two types of errors that can occur in a decision. One type of error, that of deciding that something is true when it is false (a false alarm, or running when no bear is there), is illustrated by the right end of the diagonal line. The other type of error, that of deciding that something is false when it is true (a miss, or sleeping when a bear is attacking) is illustrated by the left end of the diagonal line. Note that as one type of error goes down or is reduced, the other type of error goes up or increases.

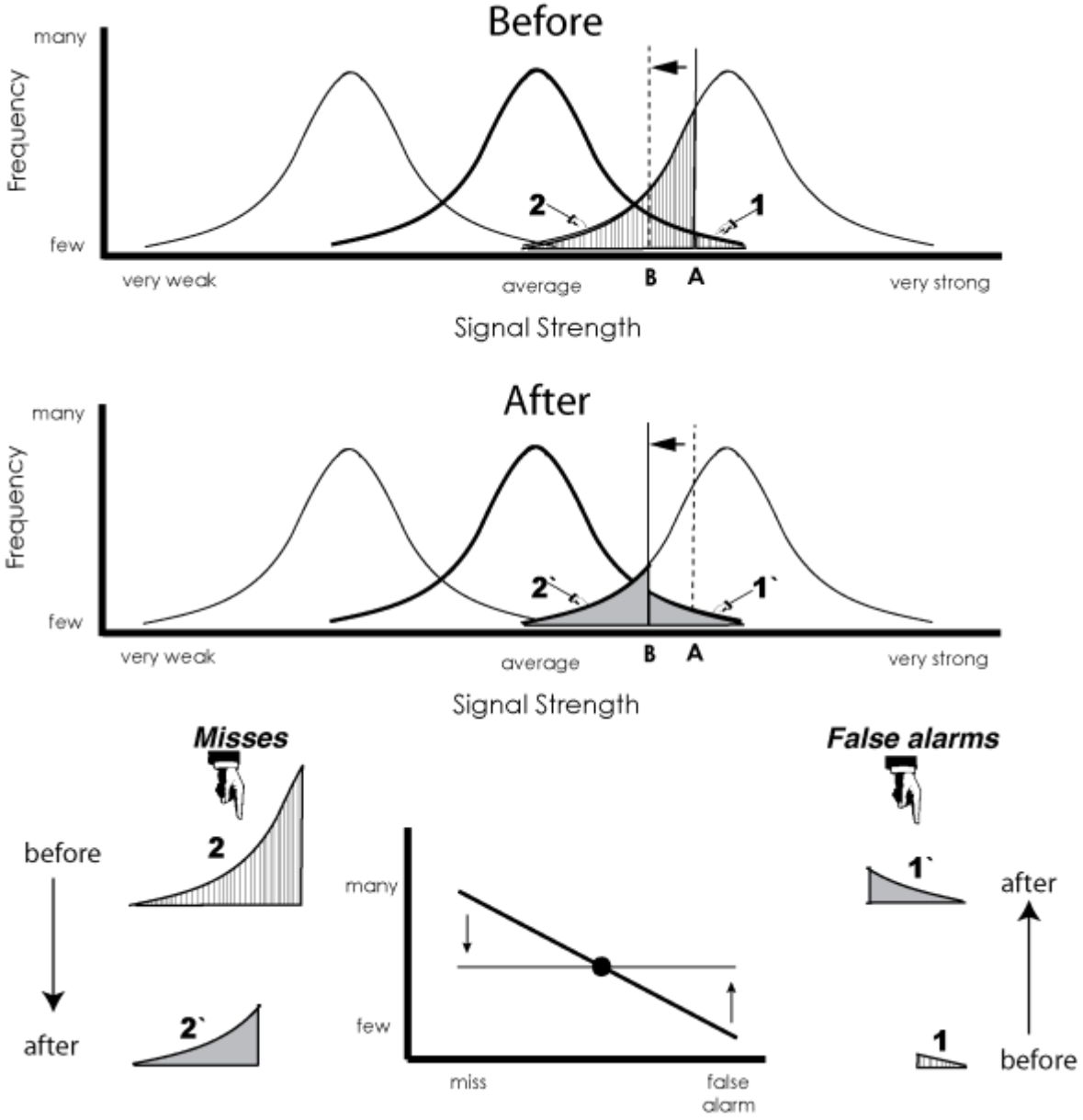

Figure 3.21 The seesaw representation of false alarms and misses (lower section) with the segments of the distributions representing misses and false alarms added to the right and left of the lower section. As misses are decreased (the left two distribution segments labeled 2 and 2'), the size of the area of the distribution representing false alarms increases (the right two distribution segments labeled 1 and 1'). The source of these segments can be seen in the upper portion of the figure.

Figure 3.21 simply combines the previous information given in this section (V) and shows why the inverse relationship works the way it does. This issue is presented in more detail in Chapter 12.

The upper frame depicts the distribution of background noise in the center with a Gaussian distribution drawn with a heavy line. The signal plus noise distribution is depicted to the right of the noise distribution with a Gaussian distribution. The distribution to the left is a reminder that the signal plus noise distribution can be anywhere on the *x*-axis. This upper frame depicts a decision

criterion at "A" on the *x*-axis. This is how strong the signal must be to warrant a decision that a signal plus noise happened. This criterion generates a distribution of false alarms labeled "1" and a distribution of misses labeled "2". These two segments are represented in the bottom frame as "1" and "2".

The middle frame shows the effect of reducing the criterion on the x-axis to the point labeled "B." In this case, the distribution of false alarms is increased in number and labeled "1′". Similarly, the distributions of misses are reduced by this new criterion and are labeled "2′". This change is referred to as making the criterion laxer. Moving the criterion further from the mean of the noise is referred to as increasing the criterion's stringency.

The bottom frame depicts how the size of the false alarms and misses change as the result of the relaxing of the criterion. The false alarms increase and the misses decrease as is indicted by the change in the "see saw."

In sum, Figure 3.21 represents the size of the distribution cut off by the criterion. The right two figures labeled 1 and 1′ illustrate the area of the noise distribution more extreme than the criterion. Recall that it is part of the original baseline noise distribution that is cutoff by the criterion. The area of the triangle-like figure indicates the probability of making a false alarm (running for nothing).

The area of the signal distribution within the criterion labeled 2 and 2′ is illustrated to the left of the diagonal line and indicates the probability of making a miss (sleeping when attacked). This is the part of the signal distribution that is cutoff by the criterion.

Note that as either false alarms or misses are made smaller, then the other gets larger.

B. Summary of the Solution Strategy to Optimize Cost/Benefit Ratio of Decisions

In sum, we optimize the cost benefit ratio of decisions by adjusting the proportion of obtained false alarms and misses. If false alarms are twice as bad as misses, then we adjust our decision criterion to make half as many false alarms as misses.

VI. Implementing Research and Evaluating the Results

Unless you already know everything, you will have to gain valid and useful knowledge about unknown phenomena. You will have to gather information, distill the important functional relationships from the data, and then provide evidence for the degree of reliability, detectability, generality and meaningfulness of your research. As a minimum, this requires that you exclude both

confounds and chance as plausible explanations for your results.

Research design is the label for procedural approaches to identifying the true cause of an effect and assuring that the effect was not a confound or a chance effect. Historically, the term "research design" was associated with the analysis of variance. That specific analytical approach required relatively formal, premeditated, and inflexible procedures and depended upon strong assumptions, and even then, it failed to provide essential information. As a result, it has a relatively narrow niche of applicability in behavior analysis. The term research design no longer implies any necessary connection to statistically-based research.

Behavior analytic research design is feedback driven and is therefore necessarily flexible. Unfortunately, this flexibility is occasionally erroneously confused with being unprincipled. In point of fact, behavior analytic research design explicitly addresses detectability, generality, and meaningfulness as well as reliability with sophisticated and comprehensive procedures that can maximize those factors. The unfortunate side effect of the informal, procedurally-based behavior analytic approach is that it is difficult for beginners to dynamically adjust their decisions and subsequent procedures based on the correct interpretation of the results, and it's easier for incompetent researchers to draw unwarranted conclusions.

A. Two Basic Stages in Research Design

1. Eliminate Confounds from Causal Factors

First compare two conditions that are exactly the same with the exception of the independent variable. The underlying logic is that differences in results are caused by differences in procedures (or chance). The control condition or control group eliminates confounds as potential causes.

2. Reject Chance as the Cause of the Effect

Determine what happens by chance. If the results you have obtained with your procedure exceeds your criterion by so much that even a critic would have to agree that your independent variable had a true effect, then declare that the procedure causes the difference in the obtained behavior rather than chance causing the effect.

Note that the consideration of cost/benefit factors is held constant while the issue of chance is presented in isolation in the following sections.

B. Two Basic Strategies of Research Design

1. Null Hypothesis Significance Testing (NHST): "Groups Design"

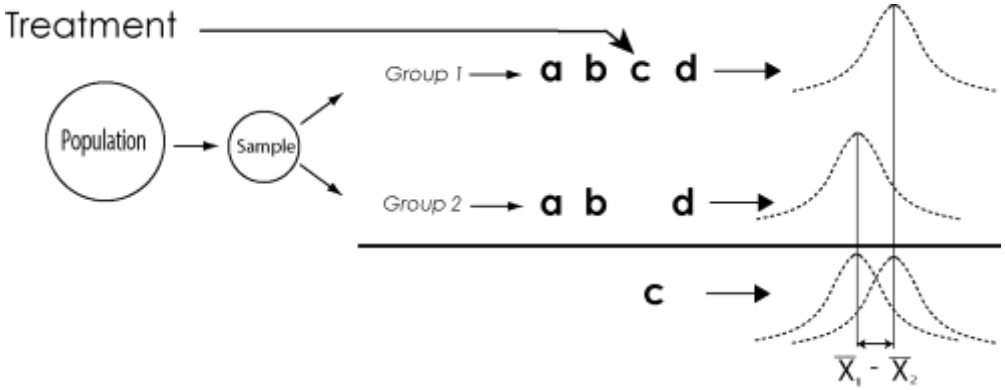

Figure 3.22 Depiction of traditional group design research. A sample is drawn from a population and is subsequently sorted into two groups. The difference in the procedures these two groups are exposed to, in this case "c", causes the difference in the means of the dependent measure (i.e., $X_1 - X_2$) (if chance is not the cause).

As depicted in Figure 3.22, a traditional Null Hypothesis Significance Testing (NHST) groups design such as the Analysis of Variance (ANOVA) starts with the population of interest. A sample is drawn from the population such that the information obtained on the sample will generalize back to the population. Two groups are formed, only one of which receives the treatment. The two groups are set up to be as identical as possible with the exception of the treatment. The difference between the means of the dependent measure in the two groups (i.e., $\overline{X}_1 - \overline{X}_2$) is then compared to the difference between means that are expected by chance. If the obtained difference is greater than the criterion, then a decision is made to act as if the treatment worked or claim that the treatment had a significant effect.

2. Behavior Analytic Research Strategy (BARS): "Single-Subject Design"

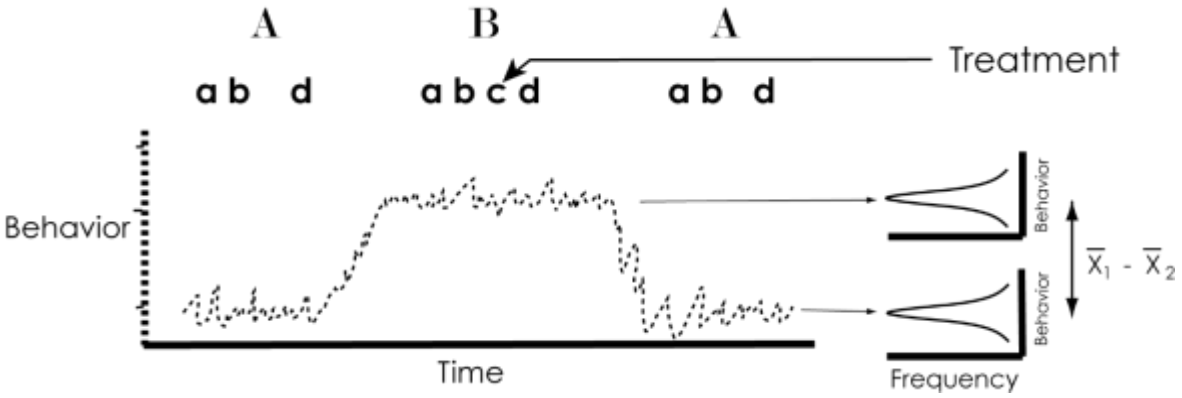

Figure 3.23 Depiction of single-subject research design. An individual's dependent measure across time is shown in the left portion of the figure. The behavior before the treatment or during baseline is indicated in the left portion of the figure (labeled A). During the treatment conditions (B), the dependent measure changes. Following the removal of the treatment (return to baseline) (A), the dependent measure returns to its former state. The right-hand portion of the figure shows the distribution of scores during the baselines before and after (lower distribution and X_2), and the distribution of scores during treatment (upper distribution and X_1). The figure depicts that the difference in the dependent measures is caused by the difference in the treatments if it is not due to chance.

The spirit of behavior analytic research differs from NHST research. First and foremost, behavior analysis is about the factors that cause an individual to behave the way they do, rather than determining the causal factors underlying the average change in an average subject. Additionally, behavior analysis is inherently experimental. Whenever a question concerning the cause of a behavior arises, the behavior analytic response is to manipulate empirical environmental variables, collect data, and understand the determinants of the resulting behavior change (a functional analysis). As a result, behavior analytic research strategy (BARS) produces a causal framework rather than some actuarial datum.

Behavior analytic research is based on how an individual changes as the result of a treatment (see Figure 3.23). Initially, a baseline measure of an individual is documented to provide a basis of comparison for the dependent measure under the treatment condition. Following a stable state under the treatment condition, the baseline condition is then reinstated. The recovery of the baseline measure is used to assure that the treatment did in fact cause the change in the dependent measure rather than a change over time caused by some other process, such as aging or satiation.

Behavior analysis makes decisions about research results based on a comprehensive albeit informal criterion. That criterion is based on what is, in effect, multiple replications. Within subject session-to-session variance is used as a measure of error or noise. As a result, the signal to noise ratio is so great that both high reliability and high detectability is assured. Typically, decisions are made by simply observing the data to see if it shows an effect so large that all observers, including critics, would agree that there is a treatment effect. In general, the demonstration of reliability is so extreme that it can easily be done by eye in that a 10% or 20% error one way or the other would not change the decision or interpretation of the data.

Additionally, because procedure adjustment decisions in behavior analytic research can be made after only a few sessions, this type of research identifies a behavioral process very quickly. Procedural adjustments are, therefore, often systematic replications, and as replications, are a direct measure of reliability. Traditional null hypothesis research designs must run their entire course before any decision whatsoever can be made. As a result, they waste research time especially in the case of suboptimal procedures and dead ends.

Behavior analytic research prototypically demonstrates that an effect is reliable and not simply a chance effect experimentally by turning the effect on and off in each of several individuals and with each of several procedures.

Behavior analytic research explicitly addresses detectability by actively reducing the variability in the baseline (i.e., noise or "chance" distribution) by adjusting the procedures to reduce variability, by exerting extreme control over potential confounds, and by comparing individuals with themselves. Taken together, these measures reduce the noise variability to a very low level thus revealing very small effects with simple visual analysis.

Generality is established by a strong emphasis on understanding the situation and its effects on behavior and how the research situation relates to the target situation. Additionally, the single-subject approach itself provides confidence in the generality of the effect. If the effect occurs in three out of three subjects and across systematic replications, the effect is likely to generalize to other subjects and other situations.

Finally, confidence in the meaningfulness of the research is explicitly maximized by an experimental emphasis on maximizing the percent variance accounted for in each individual and in each procedure. It is an intrinsic part of behavior analytic methodology.

The flexibility of behavior analytic research as opposed to the rigid protocol required in NHST research designs is a double edge sword. NHST designs demonstrate or fail to demonstrate reliability on the basis of a rigid set of rules that cannot be adjusted to better reveal an effect, but on the other hand, they resist errors due to incompetent or unscrupulous researchers. Behavior analytic designs provide flexibility but they also permit incompetent or unscrupulous researchers to make errors (especially ones that favor their personal bias). Peer review generally provides a safety net to catch errors before publication, but by that time much research time would have already been wasted.

C. Conceptual Follow-Up: Behavior Analytic Research Versus Traditional NHST

As previously discussed, the outcome of any experiment can be the result of three causes: confound, chance, and true effect. Each investigator in any discipline is obligated to consider each and make an overwhelming case for why a claim of true effect as the cause was valid.

1. Commonalities in Behavior Analytic Research and Traditional NHST

Behavior analytic and traditional NHST research designs are essentially the same with respect to 1) the removal of confounds with the method of differences, 2) the reliance on the principle that if a result is very unlikely by chance then it could be presumed to be a true effect, and 3) with respect to decisions being based on the explicit acceptance of the inverse relationship between false alarms and misses and how the cost of those two types of errors is optimized.

Behavior analytic and traditional NHST designs are also both the same with respect to their second line of defense. 4) If a result is inconsistent with what has been previously found and the result requires some process that is different than

anything that has ever been previously demonstrated, then additional caution is warranted. In that case, the burden of proof with both null hypothesis research and behavior analytic research increases. The effect must be very effectively demonstrated with experimental procedures and convincingly argued in the discussion section with respect to why and how such a finding is plausible and why and how it is actually consistent with our paradigm if not our database.

However, there are also differences between behavior analytic research and traditional null hypothesis testing.

2. Differences Between NHST and Behavior Analytic Research

a. Weaknesses of NHST Which are Not irreconcilably Different Than Behavior Analytic Decisions

Most typically, the standard model of null hypothesis based research (the Analysis of Variance or ANOVA):

i. Starts with two groups presumed to be equal because subjects were randomly allocated to the two groups.
(However, the two groups could actually be different at the start of the experiment.)

One group is then given a treatment while the second group is not. The mean dependent measure of the treated group is then compared to the mean dependent measure of the untreated group. If that difference is greater than what would be expected by chance (e.g., less than 5% of the time), then it is assumed:

ii. That that change in the treatment mean was not chance.
(However, it could be chance.)

iii. If it was not chance that caused the change in the treatment mean, then it is assumed that under the same conditions in the future, the same effect will occur again, which is to say that it is a reliable effect.
(However, the effect is not guaranteed to be reliable.)

iv. If the treatment reliably caused the change in the treatment mean, then the researcher is willing to declare that the treatment worked.
(However, it is not the case that it was proven that the treatment worked.)

v. If the treatment worked, then it is assumed that the effect was actually caused by what the research was "trying to prove."
(However, even if the effect were reliable, it could be caused by something other than what the researcher believed was the cause.)

vi. A Statistically significant result does not imply that the effect is meaningful.
(For example, you could easily prove that cutting off a single hair makes someone lose weight. That knowledge is of no value at a weight clinic.)

vii. NHST Encourages Proofs Based on Affirming the Consequence. Often a statistical test is structured to argue that: "if the treatment worked, then the response to input *xxx* would be output *yyy*. The output *yyy* occurred, therefore the hypothesis that the treatment worked is true"

(However, this particular logic does not provide proof that the treatment worked. The logic is labeled affirming the consequence and it is flawed

b. Serious Inadequacies in NHST

There are serious inadequacies of the standard statistical model of generating knowledge for practitioners of psychology.

i. Conceptual Precursor: Determination of a Change in the Dependent Variable Caused by the Independent Variable

The core issue in determining if a treatment worked is: what was the typical value of the dependent variable when the independent variable was in effect, as compared to what was the typical value of the dependent variable when no treatment was in effect; and is that resulting difference substantially more than could be expected by chance.

(a) Detecting an Effect in Single Subject Designs

In behavior analysis, single-subject designs are used to make this comparison because they provide the most powerful technology to detect treatment effects. Single-subject designs can detect very small differences because an individual typically behaves very similarly from day to day if the conditions are the same, and therefore even if a treatment has only a small effect, the resulting behavior caused by the treatment would be noticeable, and highly unusual against an unchanging baseline.

For example, if the alien body snatchers replaced your roommate or spouse with even an excellent clone, you would probably detect something wrong because even minute differences in the behavior of a well known individual show up against the otherwise sameness of their behavior (we have all seen that movie).

Figure 3.24 illustrates this by showing many experiments across the bottom where the procedure during the treatment phase (B) is the same as during the baseline phases (A). The difference in the behavior under the two identical conditions documents how much intrinsic "noise" is in the behavior. This is illustrated with the center distribution. It is the difference between means caused by chance. Note that the center comparison distribution has very little variance and is very narrow. In the typical conduct of research, the magnitude of the difference caused by the treatment $(\bar{x}_1 - \bar{x}_2)$ (upper right portion of the figure) is compared to this distribution. That is to say, the average day-to-day behavior of a individual under the treatment condition is compared to the average day-to-day behavior without the treatment.

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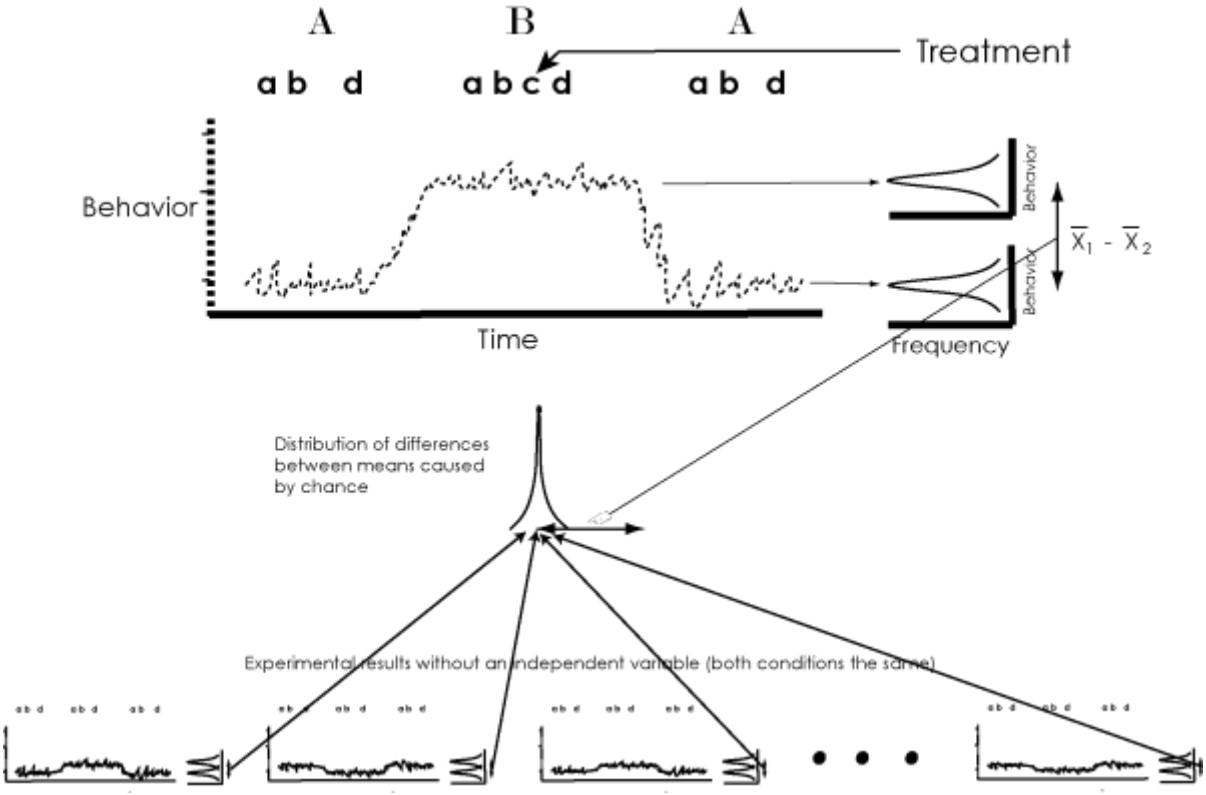


Figure 3.24 This figure depicts the logic underlying Figure 3.23, that is, a comparison of what happens in the experiment ($\bar{x}_1 - \bar{x}_2$) (the right portion of the upper section of the figure) with what could happen by chance (the distribution in the middle section of the figure which is made up of the results from the many experiments displayed along the bottom section of the figure when the treatment condition was the same as the baseline). If the difference where there was a treatment is substantially more than when there was no treatment, then the treatment is assumed to work. While this logic can be formally implemented in a null hypothesis significance test for single-subject research, more typically in behavior analysis the rejection of chance causation is via simple visual appearance. Note that the distribution of differences between means caused by chance is substantially narrower than that the distribution of chance in groups designs shown in Figure 3.25 (the next figure).

(b) Detecting an Effect in Groups Designs

Suppose you sat in on two different classes one day, and randomly selected three students in each class and counted how many questions each group asked. If the class A group, asked more, It would be incorrect to presume it was a "treatment" effect such as the professor or the nature of the class because it could be as simple as the difference in the baseline talking rates of the two sets of students that you had selected

Recall that the core issue in detectability is how different were the two groups when one group received the independent variable or treatment **as compared to** how different the two groups would be by chance if both groups received the same treatment. The difference caused by the treatment must be substantially more than could be expected by chance in order to claim that the treatment caused the

groups to be different.

With respect to detectability, the problem with group designs is that the two different groups could have notably different average behaviors even when they were treated the same. Group designs therefore require large effect sizes in order to sufficiently demonstrate a very unusual difference between the groups. As a result, any treatment effect would have to be so large as to be dramatically greater than any possible difference that could come from a difference in unequal samples of students making up the two groups or chance for you to be willing to declare that the treatment worked. Note that there is more variance in the center comparison distribution in Figure 3.25 than in figure 3.24.

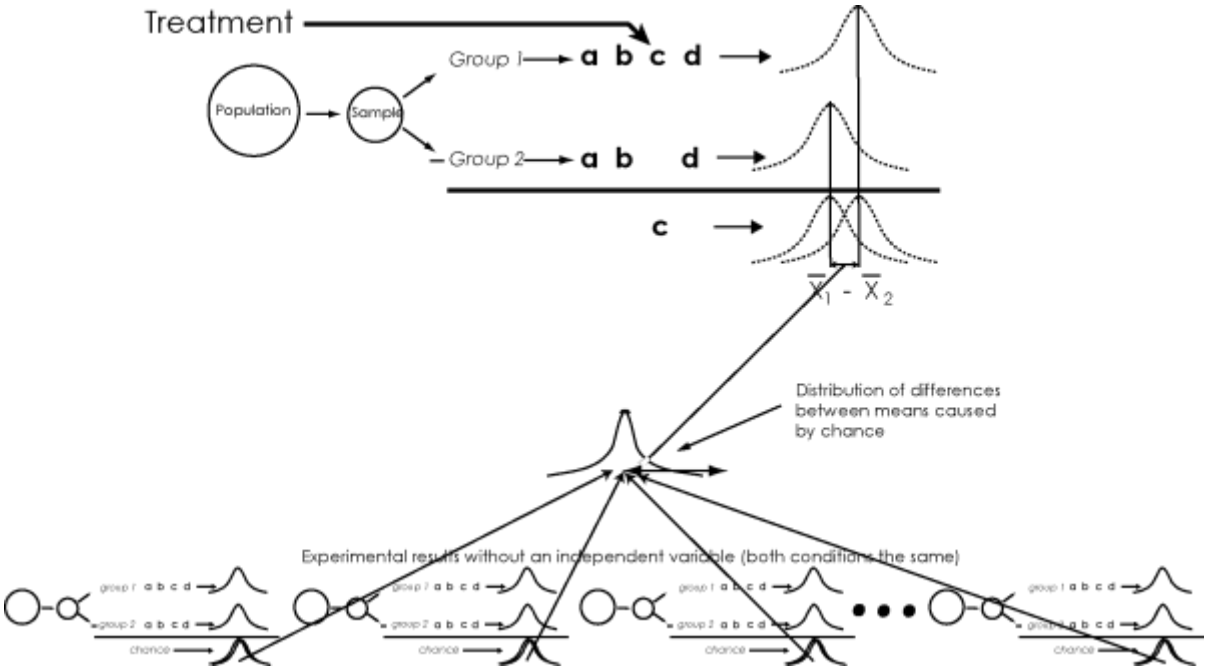


Figure 3.25 Depiction of the logic of traditional NHST group design research. The upper portion of the figure shows the difference between the means of the dependent measure (X_1- X_2) obtained following the groups being treated differently ("c"). This difference is, in effect, compared to all the results that would have occurred if very many comparisons of the two groups exposed to the exact same conditions (the bottom row of procedures and results) were collected into a distribution (depicted in the middle of the figure), and labeled the distribution of differences between means caused by chance, a standard null hypothesis significance test would then be carried out on the experimentally obtained difference as compared to the distribution of differences obtained by chance.

ii. Single Subject Designs Have Better Detectability Than Group Designs

In sum, the change in behavior that occurs with the treatment is compared to how much the behavior changes day to day when no treatment occurs. In single subject research, there is very little variance in the "noise" distribution. Therefore they can detect smaller effects of the independent variable.

iii. Reliability in NHST Designs Actually Refers to the Likelihood That the Group Average Will Show the Effect Again Not That Each Individual Will Show the Effect Again

In NHST, if the treatment worked, then it is assumed that the treatment actually worked on each individual within the group. (However, in actuality, the prediction is that any new comparison between two randomly selected groups, one of which received the treatment, will have a difference in the means within plus or minus 2 standard deviations of the difference obtained in the experiment. The prediction may not apply to all individuals. It is assumed that any difference between individuals is only random error and is therefore presumed irrelevant. The precision with which an individual can be predicted is only as good as the variance across all the individuals in the group.

In single subject research the reliability of the effect is demonstrated by the variability of the treatment across individuals to which the treatment was applied. It is an empirical documentation of the applicability of the results or reliability across individuals.

iv. Generality in NHST Designs is Based on Unprincipled and Unsystematic Intuition

Generality in NHST designs only refers to the expectation that the group average in a new situation will be the same as the original group average not that the effect is expected in each individual and in each situation. This flaw comes from depending on the representativeness of the sample, the reliability of the group average, and the similarity of the new situation to the old situation; in effect generality is based on their presumed similarity.

In single subject research, the generality is based on the understanding of the specific elements and how behavior changes as a function of those changes. Additionally, single subject research provides three replications of the effect rather than a single mean.

v. NHST Designs Squander Research Effort

NHST research asserts reliability based on the central limit theorem (i.e., the mean of; large numbers of subjects (often about 30), averaged across a large number of trials, and across a large number of sessions. As a result, the dynamics of those measures are lost and cannot be used to better understand the mechanisms controlling behavior.

vi. The Behavior of an Individual is Not Necessarily Well Predicted by a Group Average

This flaw comes from trying to predict the behavior of a specific individual based on the mean taken across a group of individuals. For example, if the mean score of a group of five people was higher on a test after drinking coffee than when not drinking coffee, it cannot be presumed that coffee will increase the test scores of each person that drinks coffee. Only if each and every individual shows an increase, can it be validly inferred that the treatment will result in a score increase for each individual. **Only the mean of the group had increased**. Some individuals in the group may have increased, some decreased, and some may have stayed the same. Even if the research question is simply "In general did the procedure increase the behavior?" only if each of the subjects react the same way, will the answer be valid within the behavior analytic paradigm. A mean taken across individuals is not a behavior analytic measure and, in point of fact, violates the paradigm because it is simply **not relevant** to understanding the behavior of any individual. The raison d'etre of behavior analysis is the understanding of causal factors underlying the behavior of an individual, rather than the average of a group. The mean behavior across individuals is a measure of group adaptation or is a sociological measure. The mean across subjects cannot answer a behavioral analytic question and is therefore an inappropriate procedure within the paradigm.

VII. Optimizing the Subject, Apparatus, and Procedure for the Purposes of the Research

The experimental analysis of behavior is most typically based on the use of pigeons pecking keys that are transilluminated with colored stimuli in sealed experimental chambers. The behavior is maintained by access to food pellet reinforcers delivered by food magazines governed by schedules of reinforcement. These choices are not an accident. Every detail of this methodology is the result of decades of optimization. The choices were maximizing solutions driven by a desire for the most reliability, generality, detectability, and meaningfulness as well as the most apt and convenient methodology. That is, the interest has been in a subject, apparatus and procedure which taken together, best reveal the laws of nature while at the same time are easy to use and inexpensive.

A. Optimized or Apt Subjects

Pigeons are the most typical species chosen as a subject in the experimental analysis of behavior. Pigeons are pests in nature (they are in no way endangered). They mature rapidly (are ready to use at an early age), and live for about 20 years (can be used for a long time). They are behaviorally stable for most of that time

(any behavior change is behavioral adaptation rather than cellular adaptation). They are small, inexpensive to maintain, easy to handle and very rarely exchange diseases with humans. They have excellent color vision.

Rats are frequently used in behavior pharmacology research because rats are mammals and their reaction to the drug treatment is similar to that exhibited by humans. However, rats are a suboptimal choice for the experimental analysis of behavior when drugs are not involved. They become senile within about a year (long time scale research is impossible) and require auditory or special cues because they have poor color vision.

B. Optimized or Apt Apparatus

The use of pigeons as subjects enables the use of colored stimuli that are easy and inexpensive to produce. Confounding light signals are easy to control in the experimental environment with a simple light tight chamber. Auditory signals are almost as easy to produce as colored lights but it is extremely difficult to eliminate confounding sounds from reaching and affecting the organism under test.

The response transducer or pigeon key is transilluminated (or back lit) because it assures that the pigeon is at least pointing its eyes at the stimulus if not actually "attending" to it while responding. Food pellets are used as the reinforcer because they are easy and inexpensive to present and remove, they are a "natural" and nutritionally balanced reinforcer, food pellets are inexpensive and easy to store, and it is straightforward to maintain a constant hunger motivation level without extraordinary procedures.

C. Optimized or Apt Procedure

The use of pigeons as subjects enables key pecking to be used as the dependent measure. Pigeons can key peck for hours with little or no fatigue and it is a behavior that can be made to "record itself." If the behavior is defined as "that which operates the key," then each occurrence of the behavior of interest is easily and reliably monitored with a computer programmed to react to each key operation. If the animal fails to operate the key, then by definition, it did not emit the behavior of interest but rather emitted some other behavior. After all, our interest is in how contingencies affect the behavior to which they are applied; not what the animal is thinking nor behaviors that look like the behavior the reinforcer followed. The programming equipment assures that the contingencies are applied to only the behavior that operates the key.

Schedules of reinforcement are procedures that explicitly and accurately control the context of behavior at the moment of reinforcement (e.g., an FR 50 assures that a peck is always reinforced in the context of 49 previous pecks). The parameters are easy to manipulate. The types of contingencies standardized in schedules are typically considered the "atoms" from which all behavioral contingencies are built. Schedules are available which control responses count elapsed time, and precise characteristics of variability.

The details of the research "sessions" procedure are an attempt to simultaneously optimize a variety of factors:

1) Enable the reliable assessment of asymptotic behavior within about 30 sessions and approximately 12 different phases per year.
2) Limit the daily workload on the researcher to 8-12 hours per day
3) Allow experimentation on 5-10 animals in each experimental chamber each day
4) Provide the maximum number of exposures to the relevant relationships each session
5) Limit satiation across the daily session and hold deprivation constant across that daily session.

It is important to note that no one is interested in training pigeons to do tricks nor in how hard a pigeon will work for food. When studying gravity, one drops objects in a vacuum, not because that's the situation in the everyday world you are trying to predict into. Rather the vacuum removes the confound of air resistance and the flight dynamics of the object being dropped. For example, a fixed ratio schedule is a way to study the effect of fixed amounts of behavior being the discriminative stimulus for a reinforced response. The fact that piecework schedules in a factory are fixed ratio schedule is irrelevant to the usefulness of fixed ratio schedules in research.

CHAPTER 4

Behavior Analysis Within Its Context

I. Conceptual Precursor: Fourier Analysis Metaphor for Understanding Variance or Change and its Constituent Components

II. Conceptual Precursor: Graphical Representation of Environmental Change and the Resulting Change in the Dependent Measure

III. The Paradigmatic Context of Behavior Analysis (i.e., Psychology) Within Science

A. Molarity of paradigm or level of analysis (unit domain)
   1. existential adaptation
   2. atomic adaptation
   3. cellular adaptation
   4. organismic adaptation
      a. conceptual fine point: boundary definitions
   5. group adaptation
   6. systematic adaptation

B. Divergent example of levels of molarity

C. Spatial representations of levels of molarity

D. Comparative analysis of levels of molarity

E. Comparative analysis of example independent and dependent variables as a function of levels of molarity

F. Comparative analysis of goals as a function of levels of molarity

IV. The Paradigmatic Context of Behavior Analysis Within Organismic Adaptation (i.e., Psychology)

A. Usage simplification: Behavioral adaptation" or behavior for "organismic adaptation"

B. Time scale of paradigm or hysteresis of adaptation (time domain)
   1. immediate time scale adaptation
   2. short time scale adaptation
      a. interesting side speculation

3. conceptual coda: the significance of short time scale adaptation and why behavior analysis is strongly focused on it
4. medium time scale adaptation
5. conceptual precursor: evolution
6. long time scale adaptation
7. conceptual follow-up: what aspects of behavior can evolve?
   a. evolution of behavior versus structure
   b. evolution of the time scale of adaptation
   c. evolution of the components of the functional relationship
8. conceptual speculation: potential mechanism that could increase the efficiency of genetic selection

C. Conceptual follow-up: divergent example of time scale of adaptation
D. Conceptual follow-up: comparative analysis of time scales

V. Spatial Representation of Behavioral Equilibrium Across Time and Unit Domains

A. Spherical representation of levels of molarity and time scale
   1. level of molarity as the surface of a three-dimensional radius
   2. time scale as an area on a spherical surface
B. Factorial representation of molarities and time scales

VI. Conceptual Follow-Up: Direct and Indirect Assessment of the Adaptation of Behavior

A. The emergence, acquisition, or origin of adaptation to a change in conditions (direct assessment)
   1. emergence of the topographical characteristics of the behavior
   2. emergence of the stimulus control over the behavior
B. Comparison of the asymptotic expressions of adaptation in two different situations (indirect assessment)

CHAPTER 4

Behavior Analysis Within Its Context

Initially, this text presented why you would want to build your practice of psychology on science or be a behavior analyst rather than a traditional psychotherapist. It then began developing an understanding of what science is and what it is not and how it is carried out and why. This chapter develops a coherent paradigmatic structure within which scientific psychology can be seen, and within which the different areas of Psychology can be understood.

First the various fields making up science are put into a structure based on their level of molarity in order to easily see the levels of molarity of analysis above and below psychology. The fact is, psychology is distinctly and fundamentally different than Biology and Sociology.

Then the various areas of psychology are partitioned with respect to their time scale of adaptation in order to understand the various fields of Psychology. Traditionally (but not necessarily), Behavior Analysis is focused on adaptation across the seconds-to-days time scale and is fundamentally different than perception and ethology.

When someone chooses behavior analysis as a career, they have chosen not to focus on understanding how the liver functions or how to fix a broken leg. Similarly, they have chosen not to focus on a person's ability to hear low frequencies or how migration is affected by the light cycle. For the most part, behavior analysts focus on how an individual's behavior is a function of reinforcement contingencies, what is labeled short time scale organismic adaptation or what has been traditionally labeled the field of learning.

I. Conceptual Precursor: Fourier Analysis Metaphor for Understanding Variance or Change and its Constituent Components

Figure 4.1 illustrates that measures of the natural world can be seen as the net effect of many events and processes distributed across many levels of analysis and time scales by using complex waveforms and Fourier analysis as its metaphor. Fourier's theorem states that any complex waveform can be expressed as a sum of simple sine components. In the same way that a complex sound can be seen as a combination of various frequencies, complex dynamics in nature can be seen as the result of a combination of various processes operating at a variety of levels of molarity and time scales.

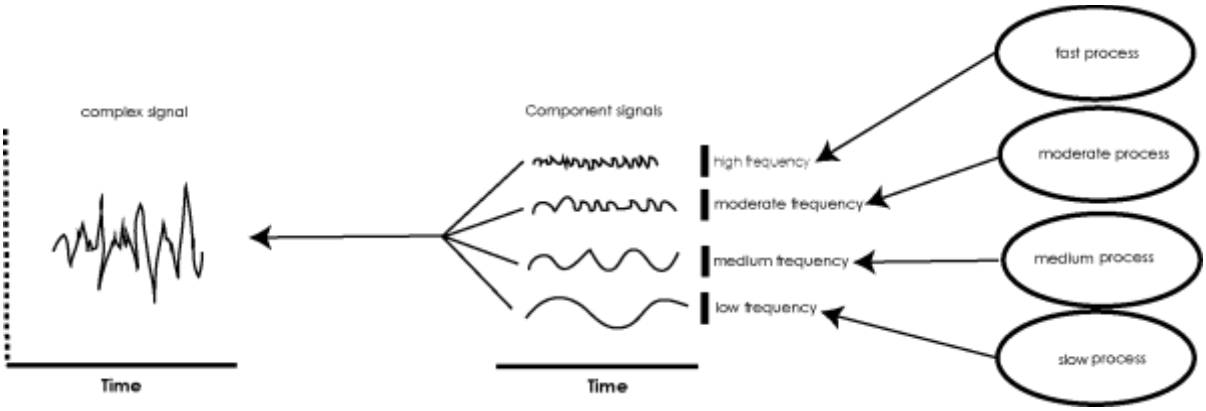


Figure 4.1 The complex waveform in the left portion of the figure represents the complex behavior of an organism that can be seen as the sum of the many different simple waveforms or subprocesses depicted in the center portion of the figure. The right portion of the figure represents the processes resulting in the various waveforms in the center portion of the figure.

An additional advantage of the Fourier metaphor is that it makes it clear that each point along the complex function of the original signal is the sum of all the component frequencies. As a result, a single point (or behavior) cannot necessarily be attributed to only one frequency (or level of molarity or time scale of adaptation). Rather, it is the net change of all the factors together that determines behavior. Sometimes an effect is primarily a short time scale effect; sometimes it is the combination of more than one time scale. This would be much like calculating a bank balance for an account which is shared by several hundred people that are depositing and withdrawing various amounts at various times. The momentary bank balance reflects the sum of all transactions, not simply one transaction of one person.

Fourier analysis asserts that the simple process of addition of various sine waves of various frequency, amplitude, and phase can adapt a straight-line function to a very complex task such as fitting a square wave. This combination of simple functions to fit something as complex as to fit a square wave would be seen as a metaphor for how an organism's behavior is adjusted by various contingencies across various time scales and levels of analysis to optimize the organism's behavior to experienced contingencies.

For example, given any starting condition, an organism could encounter for the first time a stimulus that reliably predicts some functionally important event such as food presentation. Over the seconds-to-days time scale, the organism could better adapt to the environment by coming to salivate to that predictive stimulus (i.e., short time scale adaptation). Suppose further that a wide variety of stimuli in that stimulus class all precede a variety of similar functionally significant outcomes over a relatively long time for that individual. As a result, an adaptation of the organism to the environment in the form of a relatively permanent disposition to respond to that class of stimuli would be expected (i.e., medium time scale adaptation). In fact, if the signaling relationship occurred across many individuals and across many generations of those individuals, and that relationship provided for reproductive success, an evolutionary adaptation to the

environment would be expected in the species (i.e., long time scale adaptation).

Many additional interactions between the various time scale adaptations would be available. For example, an evolutionary adaptation could occur for a species. The behavior of an individual may further adapt with the addition of some adjustment to the genetic adjustment because of specific situations that that specific individual encounters while the behavior of other individuals may further adapt with the subtraction of some components from the genetic adjustment because of their individual histories. As a result, the contribution of each time scale of the adaptation would be optimized for each individual.

II. Conceptual Precursor: Graphical Representation of Environmental Change and the Resulting Change in the Dependent Measure

The following graphic is applicable to everything from a light turning on and off to the Big Bang and the emergence and subsequent collapse of the universe.

We could represent some arbitrary change in the environment such as would be considered an independent variable in an experiment with a heavy line, and then Figure 4.2 would show the environment changing from a baseline (an

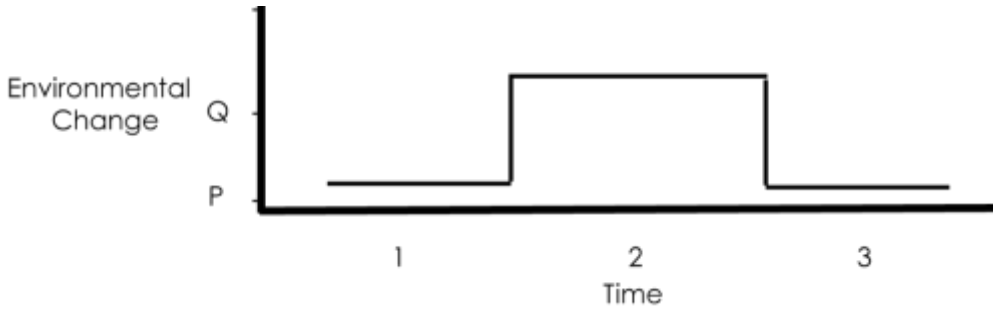


Figure 4.2 The state of some environmental condition (e.g., an independent variable) could change from State P at Time 1 to State Q at Time 2 and back to State P at Time 3.

event or set of relationships, contingencies or rules) at Time 1 to an altered state or some different set of contingencies at Time 2, then subsequently returning to the original baseline state at Time 3 (e.g., ABA design).

We can also depict the change in some resulting measure (such as would be considered a dependent variable in an experiment) as depicted in Figure 4.3.

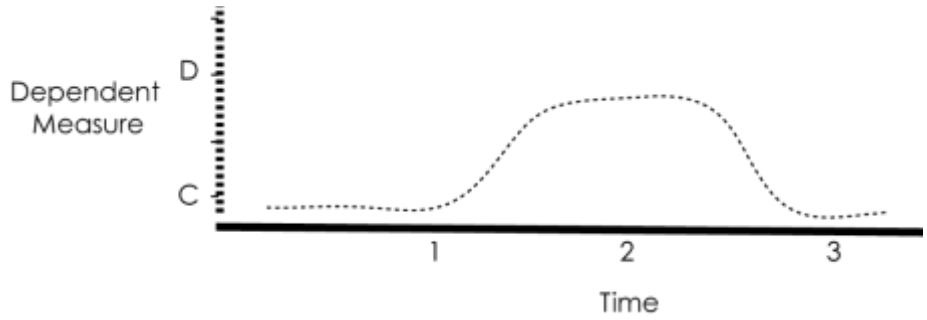


Figure 4.3 The state of some measure (e.g., a dependent variable) could change from State C at Time 1 to State D at Time 2 and back to State C at Time 3.

The state of the dependent variable could change from State C at Time 1 to State D at Time 2 and back to State C at Time 3.

Alternatively, the state of some dependent variable could change from State F at Time 1 to State E at Time 2 and back to State F at Time 3 (figure 4.4).

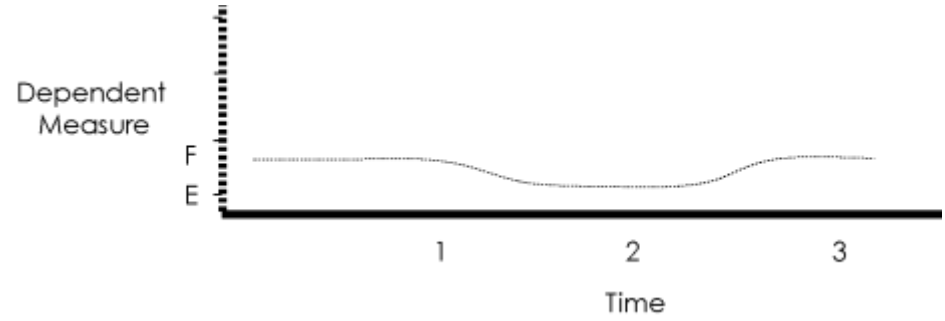


Figure 4.4 The state of some measure (e.g., a dependent variable) could change from State F at Time 1 to State E at Time 2 and back to State F at Time 3.

This change in the entity being measured is labeled the behavior of that thing. It could be the behavior of a planet, the behavior of an atom, or the behavior of an organism.

If we scale the *y*-axis for the independent and dependent variables so that the vertical change in both measures is relatively the same (in height and direction), we can then superimpose the change in the dependent variable onto the change in the independent variable, and draw the two as one figure to emphasize the relationship between the two changes in nature, we would obtain the following as depicted in Figure 4.5.

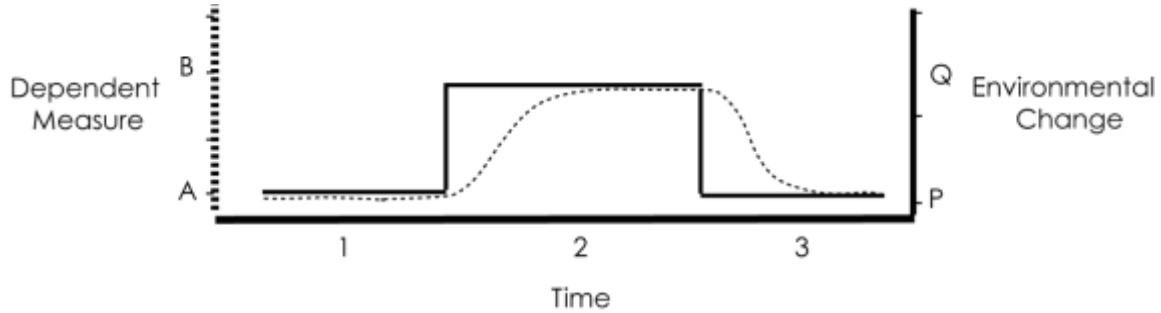


Figure 4.5 The dependent variable is at equilibrium (State A) with the independent variable (State

P) at Time1. The independent variable changes from State P to State Q at Time 2. Following some time lag, the dependent variable changes and comes into equilibrium with the independent variable (State B). At some later time, the independent variable changes back to State P. This is followed after some lag by the dependent variable returning to equilibrium with the independent variable (State A).

Figure 4.5 illustrates that the dependent variable (measured from A to B on the left y-axis) is at equilibrium with the independent variable (measured from P to Q on the right y-axis at Time 1). At Time 1.5 the independent variable changes from State P to State Q. Following some time lag, the dependent variable changes to State B and comes into equilibrium with the independent variable conditions. At some later time, the independent variable changes back to State P. This is followed after some lag by the dependent variable returning to State A and re-equilibrating.

The dependent variable is to be seen as initially in some equilibrium with the environment. The environment then changes and the dependent variable re-equilibrates to the changed environmental state. As can be seen, this adaptation can be reversed. (In fact to establish the existence of a causal relationship between the IV and the DV a reversal [or some other control procedure] must be implemented.)

Even though the time along the *x*-axes is the same for both the IV and the DV, recall that the height and direction of change in the dependent measure has been normalized to correspond with the height of the independent variable and is not measured in the same *y*-axis units and is not necessarily even in the same direction as the independent variable. The independent variable could be getting larger and the dependent variable could be getting smaller.

As can be seen in Figure 4.6, the initial state of behavior could be said to be in equilibrium with the initial state of the environment. When the environment changes, the behavior does not change at exactly the same time as the environment. There is a time lag even if it is infinitesimally small between the environmental change and the behavioral shift. (The term for this property is hysteresis. The term for the lag itself is latency.) Eventually the behavior comes into equilibrium with the environment. When the environment returns to its original state, the behavior re-equilibrates.

The change in the solid function (P to Q and back to P) could be labeled the procedure. The change in the dotted function (A to B and back to A) could be labeled the behavior change. The functional relationship between the two (A with P, B with Q, and a return to A with P) could be labeled adaptation. The difference between the dependent variable at time 2 and time 1 or 3 can be labeled the descriptive object or unit of analysis.

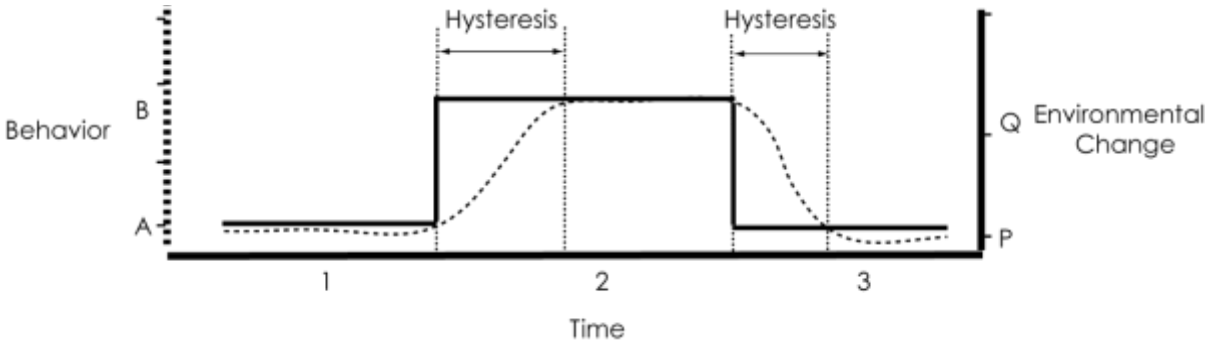


Figure 4.6 After an initial state of equilibrium between the independent variable and the dependent variable, the independent variable changes from State P to State Q. Following some time lag the dependent variable changes to State B and comes into equilibrium with the new value of the independent variable. At some later time, the independent variable changes back to State P. This is followed after some lag by the dependent variable returning to State A and again coming into equilibrium with the independent variable. The figure draws attention to the hysteresis in the change in the dependent variable following the onset and offset of the change in the independent variable.

III. The Paradigmatic Context of Behavior Analysis (i.e., Psychology) Within Science

This section details how psychology fits within the larger class labeled science. Scientists ask "why" of changes in nature. The challenge is to generate a valid paradigmatic answer. We must see change within a coherent framework. The following sections present two dimensions within which activities trying to correctly understand change can be characterized. The terminology will be "equilibrium of adaptation" to emphasize that the change in a phenomenon can best be seen as the new equilibrium in the dependent measure resulting from a change in the environment. Following an additional change in the environment, the equilibrium state of the dependent variable could change again.

Traditionally each area of science is taught in isolation; therefore, the fields within science appear to have their own premises, descriptive units of analysis, and explanatory frameworks. These apparently divergent paradigms are presented within a unifying context in the following section to emphasize their continuity.

The first dimension of the structure containing all sciences is the molarity of the paradigmatic context. Essentially the same figure could be used to characterize each of what has come to be known as the various scientific disciplines. Only the molarity (and as we will subsequently see in the next section, the time scale) of the figure changes.

A. Molarity of Paradigm or Level of Analysis (Unit Domain)

The various paradigmatic contexts of scientific investigation can be grouped in terms of the molarity of the subject matter. Each context is distinct because what the measures point to are distinctly different. Measures are typically not obtained for every level of molarity in a particular experiment. (Phenomena at a particular level of molarity always exist; it's that our specific measures don't isolate or react to every change at every level of molarity.) Building on the auditory Fourier Analysis metaphor, a person could attend to only the sound of the first violin rather than all the instruments making up a symphony orchestra.

The most familiar changes in level of molarity are those from an individual organisms versus a group. When measures are taken from a group, the data from each individual are not maintained separately. Similarly, when measures of an individual's behavior are obtained, the measures relating to each of an individual's cells are ignored.

1. Existential Adaptation

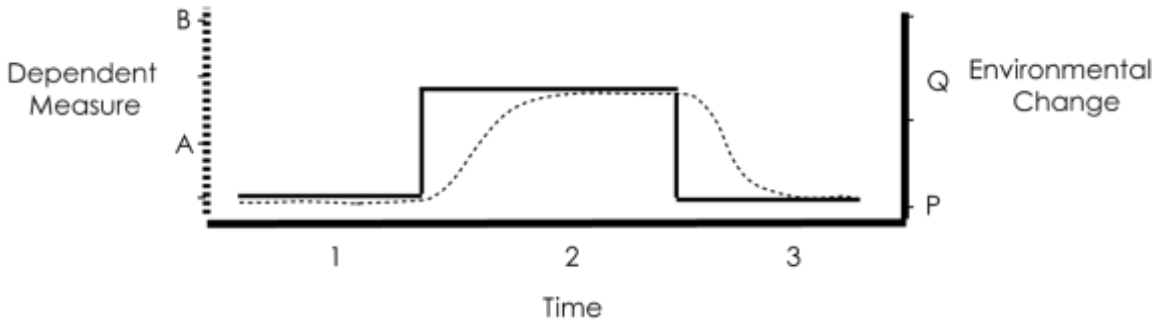


Figure 4.7 Initially what could be considered a dependent variable at the quantum level is in equilibrium with what could be considered an independent variable at the quantum level. The state of the independent variable changes. After some lag, the dependent variable changes state and comes into equilibrium with the new value of the independent variable. At some time later, the independent variable changes back to its original state. After some lag the dependent variable returns to it original state and again comes into equilibrium with the independent variable.

Existential adaptation (Figure 4.7) involves the adaptation of existence itself (more precisely, the strong force, the weak force, electromagnetic force, and gravity). The basic forces in the universe adapt as a function of interacting. (The remaining basic forces are the "environment" for the one under consideration.) University courses in this area are taught in the Physics Department. A typical type of problem is determining how atoms and their functional properties are the result of quantum mechanics

Note! "Existential" in this usage does not refer to a French philosophical view of life. Both terms do however have their root in the word existence. "Existential" is the adjectival form of "existence."

2. Atomic Adaptation

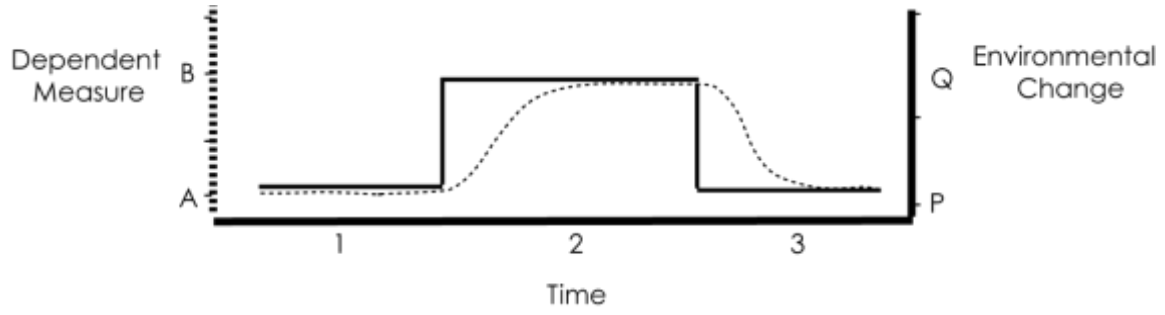


Figure 4.8 Initially what could be considered a dependent variable at the atomic level is in equilibrium with what could be considered an independent variable at the atomic level. The state of the independent variable changes. After some lag, the dependent variable changes state and comes into equilibrium with the new value of the independent variable. At some later time, the independent variable changes back to its original state. After some lag the dependent variable returns to it original state and again comes into equilibrium with the independent variable.

Atomic adaptation (Figure 4.8) involves the adaptation of atoms (more precisely, atomic structure or the statistical positioning of electrons, protons, and neutrons). For example, when brought into conjunction under the right conditions the atoms of hydrogen and oxygen adapt thereby forming water. University courses in this area are taught in the Chemistry Department.

3. Cellular Adaptation

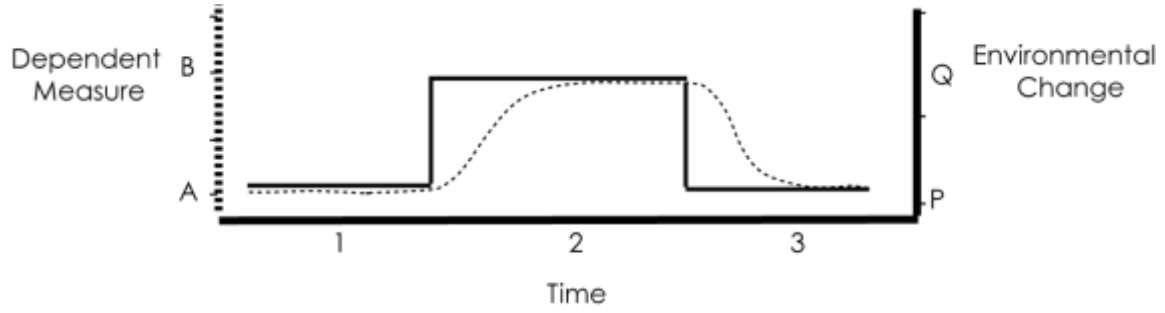


Figure 4.9 Initially, what could be considered a dependent variable at the cellular level is in equilibrium with what could be considered an independent variable at the cellular level. The state of the independent variable changes. After some lag, the dependent variable changes state and comes into equilibrium with the new value of the independent variable. At some time later, the independent variable changes back to its original state. After some lag the dependent variable returns to its original state and again comes into equilibrium with the independent variable.

Cellular adaptation (Figure 4.9) involves the adaptation of cells to changes in the environment (more popularly, the various activities labeled life). This adaptation like all others can be seen across a variety of time scales. A cell may adapt immediately to various environmental influences by contractions or

secreting a substance (functioning); a cell (more accurately, a DNA pool) may also adapt over many generations by "changing" into a cell with other characteristics (evolving). University courses in this area are taught in the Biology Department.

The effect of this level of process on the more molar level of analysis, organismic adaptations, would be exemplified by the effects of brain activity on behavior.

4. Organismic Adaptation

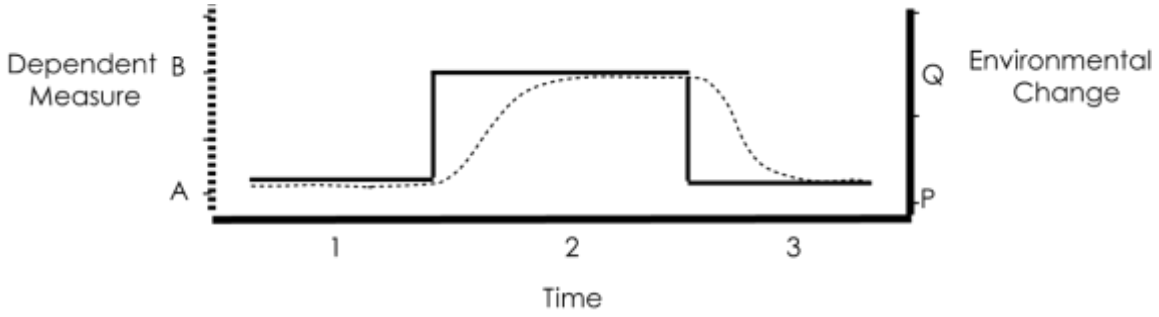


Figure 4.10 Initially what could be considered a dependent variable at the organismic level is in equilibrium with what could be considered an independent variable at the organismic level. The state of the independent variable changes. After some lag, the dependent variable changes state and comes into equilibrium with the new value of the independent variable. At some later time, the independent variable changes back to its original state. After some lag the dependent variable returns to it original state and again comes into equilibrium with the independent variable.

This class of adaptation (Figure 4.10) involves the adaptation of the behavior of a whole life form (not the adaptation of a constituent cell) to changes in the environment. If a measure of the behavior of an entire organism is altered as a function of changes in the environmental conditions, then the behavior of the organism is said to have adapted. That is to say the necessary and sufficient elements of this scale of adaptation is an environmental change and a change in the behavior of an organism. A pigeon coming to peck a key as the result of a contingency instantiated between key pecks and food presentations is an obvious example. A dog coming to salivate to a bell as the result of a contingency instantiated between the occurrence of a bell and subsequent meat powder is a second example. Elaboration of the various time scales of adaptation for this level of molarity will be covered in the next section. University courses in this area are taught in the Psychology Department.

a. Conceptual Fine Point: Boundary Definitions

There are some interesting and fundamental questions pertaining to category boundaries. A key peck or lever press followed by food with its subsequent increase in the operant is easily categorized as organismic adaptation. A bell followed by meat powder with its subsequent increase in salivation to occurrences of the bell is equally easy to categorize as organismic adaptation.

However, a challenging, albeit hypothetical, situation could be envisioned. Suppose a device was placed in a stomach which could increase the temperature of one spot, squirt a concentrated fatty substance onto the stomach lining, and could measure the production of lipase. Suppose further that activation of the heater was shown to have no effect on lipase production, and that the fatty substance squirter resulted in lipase production.

Then if a typical Pavlovian conditioning procedure of lipase production following the heat stimulus resulted in a CR, and the functional properties of the preparation was empirically shown to mimic typical Pavlovian conditioning, then; the empirically obtained phenomenon would be considered Pavlovian conditioning, the empirical preparation would be considered organismic adaptation, and the research topic would be appropriate for behavior analysis. It should be emphasized however, that this categorization is applicable only to empirically obtained externalized data, and not at all to speculations.

5. Group Adaptation

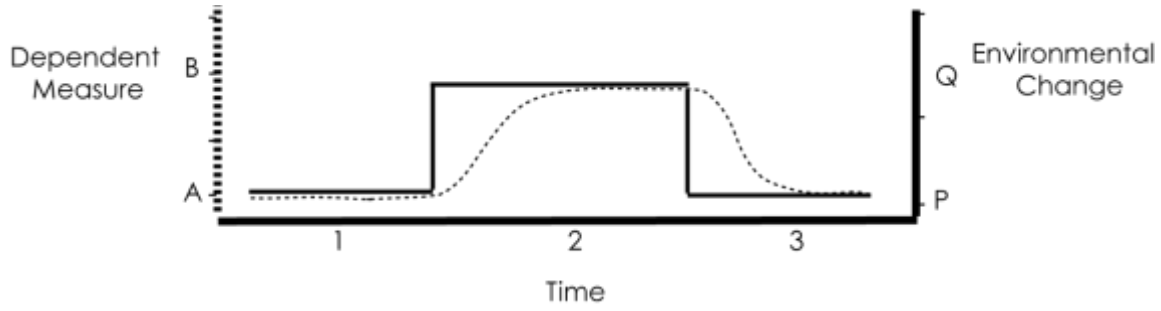


Figure 4.11 Initially what could be considered a dependent variable at the group level is in equilibrium with what could be considered an independent variable at the group level. The state of the independent variable changes. After some lag, the dependent variable changes state and comes into equilibrium with the new value of the independent variable. At some later time, the independent variable changes back to its original state. After some lag the dependent variable returns to it original state and again comes into equilibrium with the independent variable.

Group adaptation (Figure 4.11) involves the adaptation of a group (more precisely the change in the proportion of a population responding to some event in the environment). This function is labeled population dynamics. This is a purely molar property of a group and is not the behavior of any particular individual. The dependent measure could be, for example, that 63% of the population voted Republican following a policy change, but not that Harry or Mary voted Republican. Analysis of the relative frequency of Google searches, or tweets as a function of environmental events or the functional relationships between public events and what “trends” would be quintessential examples of this type of research. Because group adaptations are not often predicted based on organismic adaptation, they are frequently labeled "emergent" when the perspective is from the behavior of individuals. Time scale groupings are applicable. For example, some cultural practices once established reverse only with a new culture while

other population dynamics change quickly. University courses in this area are taught in the Sociology Department.

6. Systematic Adaptation

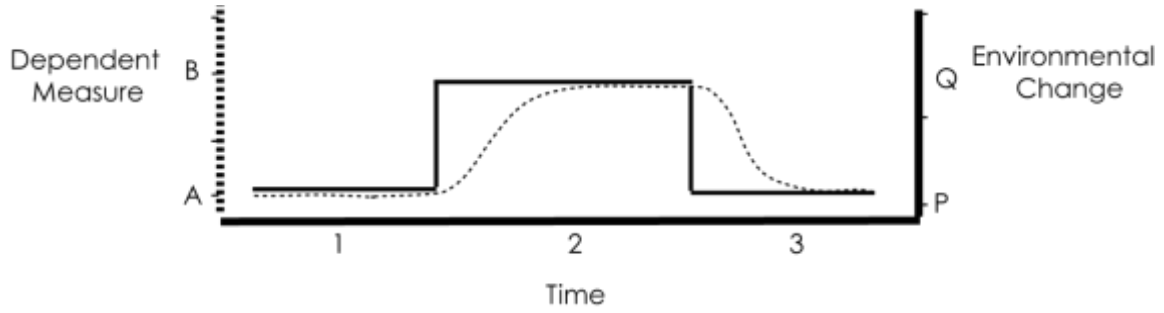


Figure 4.12 Initially what could be considered a dependent variable at the system level is in equilibrium with what could be considered an independent variable at the system level. The state of the independent variable changes. After some lag, the dependent variable changes state and comes into equilibrium with the new value of the independent variable. At some later time, the independent variable changes back to its original state. After some lag the dependent variable returns to its original state and again comes into equilibrium with the independent variable.

Systematic adaptation (Figure 4.12) is the adaptation of a system of groups, each group containing homogeneous elements such as a group of humans or a group of trees. A prototypical system is the ecosystem of a planet or a sealed-glass sphere ecosystem containing water, a few shrimps and some algae totally enclosed within a sealed glass sphere. Another example is an island with a population of foxes and rabbits. A characteristic of a system is that it is closed, or effectively so, in that there is little or no change in the input to the whole system. In effect, the dependent measure of one entity is the independent variable of some other constituent entity as in the foxes and rabbits. The study of nonlinear dynamics or "chaos" is focused on these types of changes. University courses in this area are currently taught in the mathematics department.

Note! "Systematic" in this usage does not refer to "ordered" but rather to the adaptation of a system. "Systematic" is the adjectival form of "system".

B. Divergent Example of Levels of Molarity

It is important to keep in mind that these conceptual categories or levels of molarity do not exist in isolation. An unspecific member of a group of humans is, in fact, a behaving individual which is, in turn, made up of cells which are in turn made up of atoms which are themselves made up of fundamental quantal forces. The group containing the member under discussion, in turn, is part of an ecosystem. All levels exist and function simultaneously.

A television set (as contrasted with a human) can be used as a divergent specific example:

A given television set is, at a more molecular level, made up of transistors and diodes (the person's cells). The TV's transistors (as well as the cells of an organism)

are each in turn made up of chemicals or atoms, and at the most basic level the atoms in both TVs and people are made up of quantal forces. Note that at the two most basic levels (existential and atomic) a television and a human function for the same reasons; the only difference is that the human is based on carbon chemistry while the TV is based on silicon chemistry; the fundamental forces are the same in a TV and a human and the chemical processes are the same. For example, if a researcher were interested in examining the behavior of subatomic particles in a television, then that research would predict the behavior of subatomic particles in a human. At that level of molarity, research on televisions would generalize to humans.

We can consider the levels of molarity within which an individual television set exists. The first larger set would be televisions as a population and how televisions, as a group, could be seen to change as a function of the common environment within which they all exist. Televisions as a population tend to be tuned into shows that are popular across the user population and not tuned into shows that are unpopular (just as a person is a member of a population and is more likely to be doing the same things that other members of the population are doing). At the most global level, humans and television sets are groups of entities in the large ecosystem that is the earth.

C. Spatial Representations of Levels of Molarity

The following figures illustrate the successively more molecular and more molar organization for nature. All levels exist simultaneously.

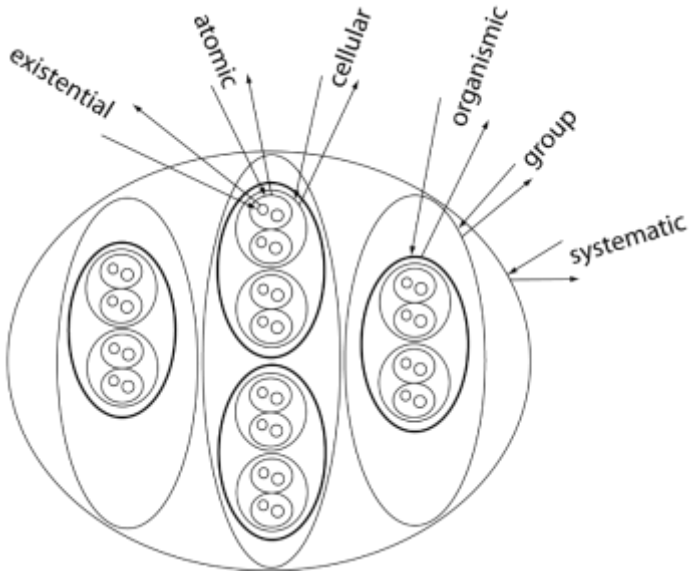
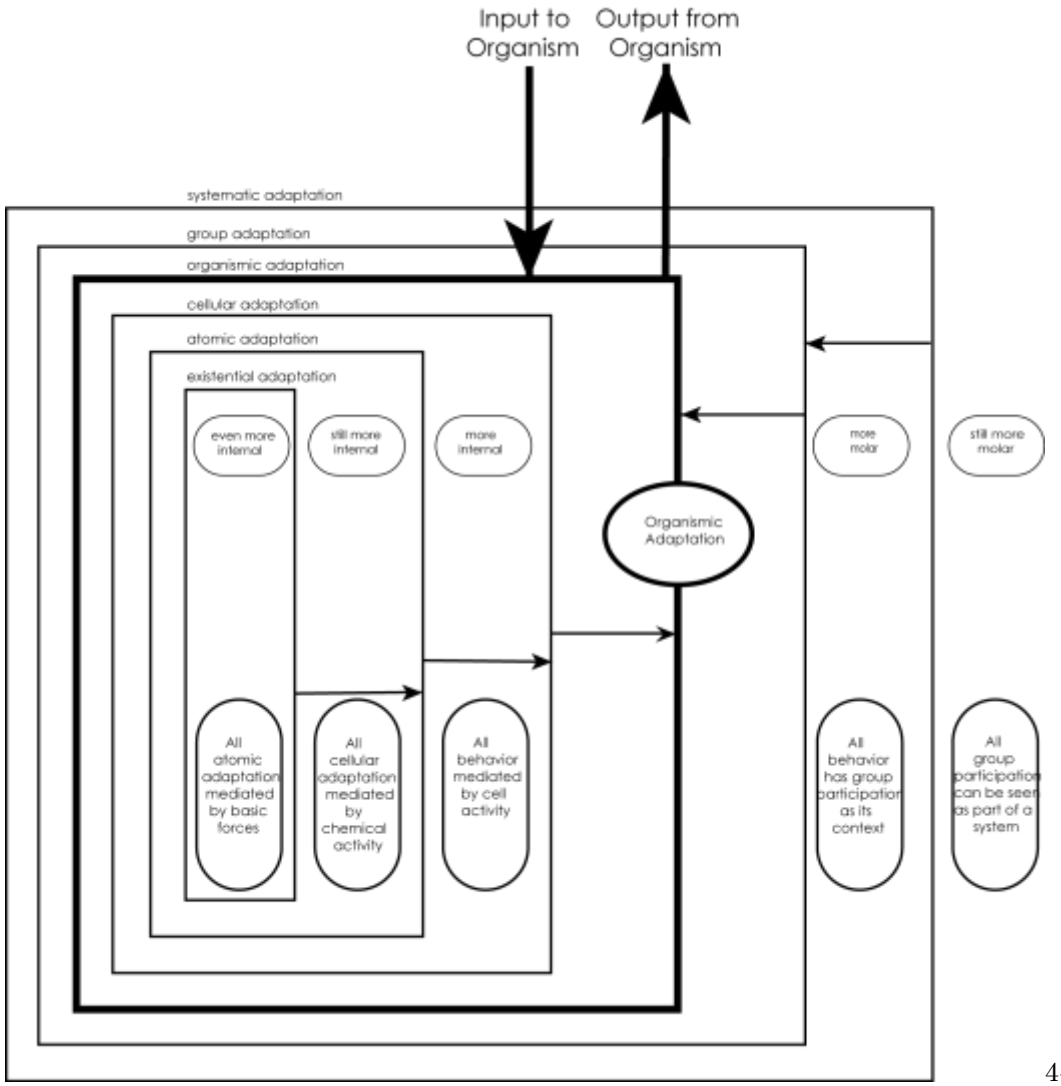


Figure 4.13 Successively more molecular levels are depicted within each level of molarity. Within a system, there are groups: within each group there are organisms; within each organism there are cells; within each cell, there are atoms; within each atom there are quanta. The behavior at each level of molarity can be seen to be the result of events happening at the same level as that of the measured behavior, rather than at more molar or more molecular levels.

Figure 4.14 is given from the organismic adaptation perspective.



4-

Figure 4.14 An organism (the box drawn with a heavy line) can be seen to behave (the bold arrow pointing up). That behavior can be seen to be a function of events in its environment (heavy arrow pointing down at the top of the figure). Alternatively, the behavior of the organism can be seen to come from the cell activity within the organism. That cell activity in turn can be seen to come from the chemical activity within the cell; that chemical activity in turn can be seen to come from quantal mechanics or basic forces within the atoms. Alternatively, organismic adaptation can be seen within the context of group adaptation, and group adaptation can in turn, be seen within the context of system dynamics.

D. Comparative Analysis of Levels of Molarity

Table 4.1 provides a detailed analysis and comparison of various aspects of the levels of molarity of adaptation. The specialties one level of molarity above and one level of molarity below Organismic Adaptation are provided.

	Cellular Adaptation	**Organismic Adaptation**	**Group Adaptation**
Global Question	Why do **neuron cells** do what they do?	Why do **organisms** do what they do?	Why do **groups** do what they do?
Descriptive Unit of Analysis (for Short time scale Adaptation)	**Connection** Semi-permanent change in behavior of **neurons**	**Learning** Semi-permanent change in behavior of **organisms**	**Participation** Semi-permanent change in behavior of **groups**
Causal Perspective (for Short time scale Adaptation)	**Connection** is caused by non random relationships in the environment of the **neurons**	**Learning** is caused by non random relationships in the environment of the **individuals**	**Participation** is caused by non random relationships in the environment of the **group**
Explanatory Reference (for Short time scale Adaptation)	Why did the organism learn? Because of the **connections between neurons**	Why did the organism learn? Because of its **reinforcement history**	Why did the organism learn? Because **virtually all individuals exposed to those contingencies learned**
Research Task Enumerate functional relationships between IV and DV	Of what are **Connections** a function of?	Of what is **Learning** a function of?	Of what is **Participation** a function of?
Example **Independent Variable**	Manipulate pattern of neuronal activity	Follow pecks with food or dirt	Expose group to one speech or other speech
Example **Dependent Variable**	Measure behavior change of **neurons** (connections)	Measure behavior change of an **organism** (learning)	Measure behavior change of a **group** (participation)

E. Comparative Analysis of Example Independent and Dependent Variables as a Function of Levels of Molarity

Table 4.2 provides an example independent and dependent variable for each level of molarity, as well as an example of the source of the behavior and the functionally significant outcomes for each level.

Paradigm Term	**Existential Adaptation**	**Atomic Adaptation**	**Cellular Adaptation**	**Organismic Adaptation**	**Group Adaptation**	**Systematic Adaptation**
Common term	Physics	Chemistry	Biology	Psychology	Sociology	Systematics
Example Independent Variable	Gravity	Valence state	Neuro-transmitter	Reinforcement contingency	Advertisement	Number of foxes
Example Dependent Variable	Reduction in separation	Compounds	Spike potential	Key pecking	Buying pattern	Number of rabbits
Example Variation Process "Provenance"	4 basic forces	Valance or charge	Genes	Immediate time scale behavior	Exposures	Non-linear dynamics
Example Selection Process "Consequence"	existence	stability	reproductive success	reinforcement	culturation	predictability

F. Comparative Analysis of Goals as a Function of Levels of Molarity

Table 4.3 presents the various scientific activities as a function of the level of molarity of that adaptation and the three potential goals at that level of activity.

Paradigm Term	**Existential Adaptation**	**Atomic Adaptation**	**Cellular Adaptation**	**Organismic Adaptation**	**Group Adaptation**	**Systematic Adaptation**
Common term	Physics	Chemistry	Biology	Psychology	Sociology	Systematics
To Understand: **Basic Research**	why existential adaptation why existence string theory	why atomic adaptation why substances	why cellular adaptation why life evolution	why organismic adaptation why behavior reinforcement theory	why group adaptation why participation	why systematic adaptation mathematical characterization of chaos
To Solve: **Applied Research**	atomic weapons research fusion research	polymer research	agricultural research medical research	clinical research educational research	organizational research cultural research	ecological research
To Dispense Solutions: **Practitioning**	architect engineer bomber pilot	Chemical sales man, gas station attendant	exterminator county ag agent, physician farmer	clinical psychologist teacher salesperson	politician law maker advertiser	Ecologist

IV. The Paradigmatic Context of Behavior Analysis Within Organismic Adaptation (i.e., Psychology)

The second dimension of the paradigmatic structure of science is the time scale of the effect of interest. If we use organismic adaptation as the example, we would be focused on how the behavior of an individual organism adjusts to the environment. We would point out that not only do life forms behave, but behavior itself adapts in fundamentally different ways and across different time scales as the result of fundamentally different interactions with the environment. In each case the effect that the adaptation could have on reproductive success is apparent. For example, a dog that runs away when a valid warning occurs but not when a random stimulus occurs will enjoy a safer and less disruptive environment and would likely contribute more genes into the pool than one that does not condition. Short time scale adaptation would be "installed" in the species.

The behavioral adaptation of an organism has many forms. Sensation/ perception, learning, developmental, and animal behavior/ethology are four seemingly distinct, nearly autonomous areas of inquiry involved in the analysis of an individual's behavior changes. In point of fact, there is continuity underlying these approaches. The appropriate perspective points out that these areas of inquiry are simply focused on different time scales of adaptation.

The continuity underlying the seemingly disparate approaches to the analysis of behavior change are made more clear by viewing them in terms of the time scale of reversibility of their functional relationships. Time scale of adaptation varies from:

1) behavior change which reverses almost immediately, such as the reporting of the presence and then the absence of a stimulus when a darkened lamp is illuminated and then turned off again (traditionally referred to as a "sensation." This class of adaptation is referred to as immediate time scale adaptation;

2) behavior change which can be reversed only after some training, but that can be reversed back and forth many times within the life of the organism (traditionally referred to as "learning.") This time scale is exemplified by coming to peck (or salivate) to the green light but not to the red light. It is the acquisition and loss of the relationship "pecking (or salivation) to green and not to red" that is of interest and which defines this class of behavior as opposed to the peck or salivation itself. This class is referred to as short time scale adaptation;

3) behavior change which is virtually permanent within an individual, once established, but that is reversible across progeny, such as personality or learning to learn (traditionally referred to as "developmental changes"). Again, it is the time scale of the acquisition and loss of this relationship that is of interest and the defining characteristic of this class of behavior rather than simply the response itself. This class is referred to as medium time scale adaptation.

4) behavior change which is typically reversible only across many generations (traditionally studied as species-typical behavior or instincts by animal behaviorists and ethologists). (Note that long time scale changes follow from variation and selection and are not based on the heritability of ontogenically acquired characteristics.) As before, it is the time scale of the acquisition and loss of this behavior that defines this behavior class, rather than simply the response.

This classification system is more arbitrary than level of molarity. First, the time scale dimension is continuous with no simple boundaries that separate one category from another. For example, a very slow immediate time scale or perceptual change could take longer than a very fast short time scale or learned behavior change.

As a specific example of the many time scales across which behavior can be seen, consider the following. If you give a person a piece of candy and they smile and salivate, what is the total "cause" of the smile and salivation? At first glance, it is certainly the stimulus of being given the candy; but further thought adds the realization that firstly, the person must be able to taste the candy (immediate time scale adaptation), and secondly, that the person learned over the course of a few experiences that those things that are wrapped in the bright blue wrapper are sour/sweet and taste good (short time scale adaptation). Further, you would accept

that it was necessary for the person to develop an enduring preference for sour/sweet candy as they were growing up over a number of years (medium time scale adaptation). Finally, it is obvious that animals developed the tendency to prefer sweet foods millions of years ago over the course of many many generations (long time scale adaptation).

The interdependence of these processes is apparent when presented simultaneously, but this fact is often overlooked because the various time scales are typically presented in isolation with other time scales held constant and taken for granted. There are many advantages to the present integrated approach. For example, the fact that a functional relationship can be confounded comes as no surprise to anyone. However, functional relationships are often not conceptualized with respect to all of the time scales across which they developed. The discovery in the 1950s that sensory capacity was importantly affected by reinforcement contingencies (theory of signal detection) led to the most significant change in that field in over a century. A more recent reminder of the interaction of time scales occurred in the 1970s when many learning theorists were surprised because they had overlooked the obvious importance of evolution in determining which functional relationship could be learned. In sum, no behavior is the result of variables operating in only one time scale exclusive of all others. Behavior does not exist apart from perceptual, learning, developmental, and phylogenic factors, and these must be held constant if their variation alters a functional relationship. If experience across a time scale other than the specific one of interest to the research is a source of confounding, then it is simply an interaction to be understood and held constant and controlled or deliberately manipulated as an independent variable.

While in broad strokes, immediate, short, medium, and long time scale adaptations capture the important and critical difference in categories of adaptation. The devil is in the details. For example, the time of an immediate time scale adaptation is altered by the activity the organism is doing when the stimulus occurs. Short time scale adaptation is faster or slower depending on the complexity of the task, and long time scale adaptation is a bit of a misnomer in that it is generations not simply the passage of time that determines the duration of the adaptation and the dependent measure is the change in the proportion of a population with a behavior not the change in the behavior of an individual. A second detail is that often only a single aspect of the behavioral adaptation is considered. For example, in short time scale adaption, only the behavior immediately before the reinforcer is considered to be the dependent variable.

The present integrated perspective provides the most useful context to view obtained data and provides the questions that most effectively advance our ability to predict behavior. This time scale continuum also provides the necessary frame of reference for explanations of functional relationships which invoke mechanisms from more than one time scale, such as the suggestion that ethological or developmental variables account for an important portion of the variability obtained in a learning task. In sum, the various types of behavioral adaptations studied by psychology can be categorized in terms of their time scale of adaptation.

In the same way levels of molarity can be illustrated with the same figure by

changing the labeled independent and dependent variables, all organismic adaptations can be illustrated with the same diagram by only changing the time scale across the *x*-axis.

A. Usage Simplification: "Behavioral Adaptation" or "Behavior" for "Organismic Adaptation"

From this point on, our exclusive interest in this text is with the behavior of individual organisms. As a result, the correctly descriptive but cumbersome construction of "organismic adaptation" or "organismic behavior" can be eliminated because it is assumed that any reference to behavior refers to the behavior of an individual organism rather than the behavior of planets or the behavior of atoms or the average behavior of a group of individuals unless explicitly specified otherwise.

This simplification has two additional benefits. It does not imply that there are dependent measures other than behavior in the field of psychology and it removes the organism qua organism from diverting our attention and efforts away from the behavior of the organism.

B. Time Scale of Paradigm or Hysteresis of Adaptation (Time Domain)

It is important to note that the following four groupings refer to the time course of the dependent variable, not simply the state of behavior before and/or after some stimulus changes.

At its most fundamental level, all organismic adaptation research is necessarily based on the reactions of an individual organism or the expression of a behavior with respect to an environmental change. The dependent measure in immediate time scale adaptation is necessarily a functional relationship between some environmental condition or stimulus and a behavior of the organism. The occurrence of a behavior is labeled a reaction or the expression of a behavior.

For comparison, in immediate time scale adaptation the independent variable is the stimulus change, the dependent variable is the actual behavior itself such as a key peck. On the other hand, the independent variable in the short time scale adaptation case is the reinforcement contingency, while, the dependent variable is "learning." learning is an acquired adaptation in the behavior (e.g., key pecking a green key), such as a change from responding to red to responding to green. The change in a functional relationship between the environment and behavior in short time scale adaptation is labeled the emergence of a functional relationship, or the emergence of an adaptive behavior.

The variations in research questions on organismic adaptation are the analysis of the factors that alter or modify functional relationships across different time scales. The following conceptual organization partitions behavior changes into broad general classes based on the time scale across which those functional relationships typically come into equilibrium or adapt to new environmental conditions.

1. Immediate time scale Adaptation

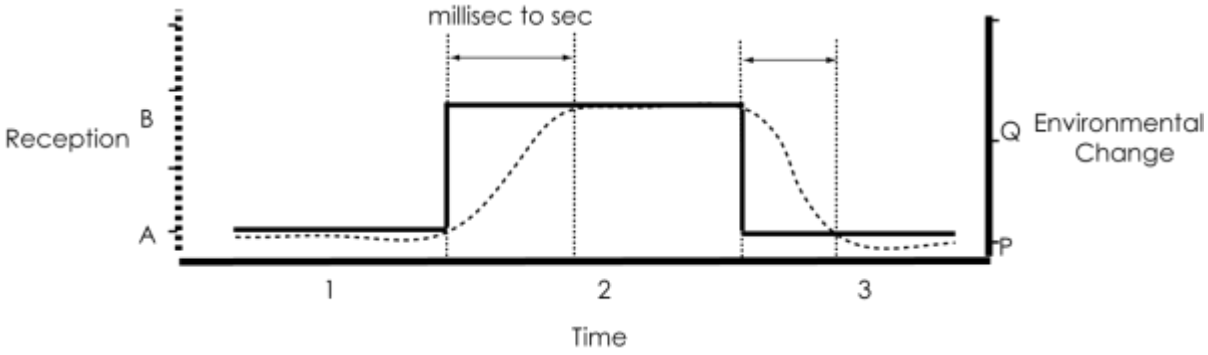


Figure 4.15 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag in the milliseconds to seconds range the dependent variable changes to State B and comes into equilibrium with the new value of the independent variable at Time 2. At some later time, the independent variable changes back to State P. This is followed by a lag in the milliseconds/seconds range of the dependent variable returning to State A and again coming into equilibrium with the independent variable at Time 3.

The exemplar of immediate time scale adaptation (Figure 4.15) is an individual saying "I see it" when a light goes on. The measured behavior is a behavior difference to a stimulus difference or a "reaction." For example, the light is off and the person is quiet; the light goes on and the person says, "I see it." The light goes off again and they stop saying "I see it."

The IV is a stimulus change; for example, turning on a green light. The DV is a change in a behavior under the control of the stimulus change or a "reaction." For example, a person saying "I see a green light" or pushing a button when a green light is turned on; and no longer saying I see the light or no longer pushing the button when the light goes off. The statement or button push take a finite amount of time to occur even if it is only a split second which is the source of the hysteresis at this time scale.

Note that any change in behavior under stimulus control regardless of the time scale of the origin of that functional relationship would qualify as an immediate time scale adaptation. For example, the expression of a key peck when a key turns green, because of a functional relationship that had been established via short time scale adaptation; and the expression of salivation to meat powder in the mouth because of a functional relationship that had been established via long time scale adaptation across evolutionary time, are both instances of immediate time scale adaptation. These adaptations most typically occur immediately following the stimulus presentation, as soon as the organism "experiences" them. For example, presenting a green light is followed immediately within a few milliseconds by the person saying "I see the light." It is a behavior change as soon as the stimulus changes.

To repeat, what made the organism behave that way to that stimulus is irrelevant to this time scale of adaptation. A bird may peck a green key "for the

heck of it;" because it had been conditioned to peck a green key; because it had a broad reinforcement history for pecking things; or because that particular species had an instinct to peck green things.

Research in immediate time scale adaptation could document the change in the probability of a reaction as a function of stimulus intensity. Often immediate time scale research is directed to the specific aspect of the stimulus that is controlling the behavior (e.g., wavelength) or the capacity of the organism (e.g., detection threshold).

The **c**hange **i**n **b**ehavior (CIB) can be: saying "I see the light," it can be a dog salivating to meat powder, or salivating to a bell which had been paired with meat powder.

In a computer metaphor, because this adaptation is easily reversed, it is like RAM memory (the state of the output of the memory reverses as soon as its activator is removed).

Immediate time scale adaptation is characterized by:

(1) a stimulus change controls a response
(2) an exemplar is an individual saying "I see it" when the light goes on
(3) Premise: An external event can change the behavior of an organism.
(4) Descriptive unit of analysis: "Reaction" which is a change in the behavior of the organism associated with changes in the environment. This behavior reverses with the stimulus.
(5) hysteresis in milliseconds - seconds range
(6) the research area is also known as "sensation/perception"
(7) a typical research topic – threshold determination
(8) Explanatory framework: Why did the organism respond? Because the stimulus changed.

2. Short time scale Adaptation

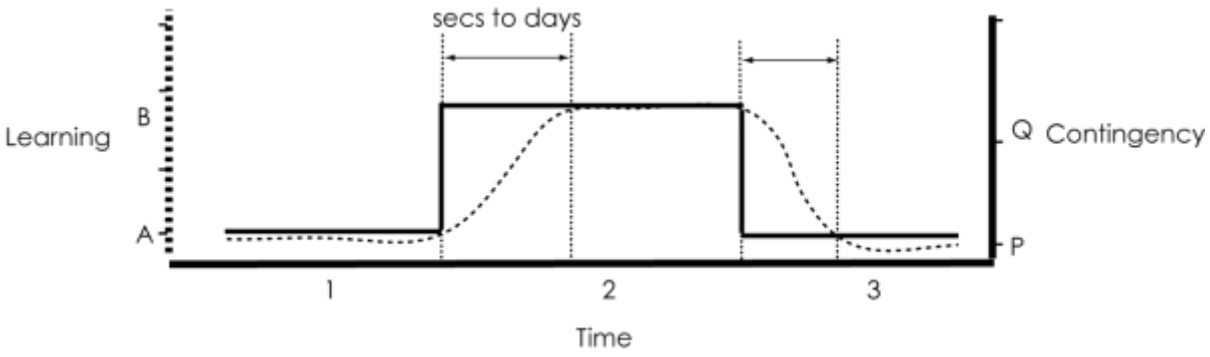


Figure 4.16 After an initial state of equilibrium between the independent variable and the dependent variable, the independent variable changes from State P to State Q. Following a lag in the seconds to days range, the dependent variable changes to State B and comes into equilibrium with the new value of the independent variable. At some later time, the independent variable changes back to State P. This is followed a lag in the second/days range of the dependent variable returning to State A and again coming into equilibrium with the independent variable.

The prototypical exemplar of short time scale adaptation has come to be "a pigeon learning to peck a pigeon key."

Until the 1900s, it was presumed that lower animals could not exhibit this class of adaptation (ontogenic adaptation). Recall that Pavlov was not surprised by stomach secretions to meat powder in the mouth because it was plausible that that secretion was an inborn "instinct." However, he was amazed at stomach secretions to the animal caretaker after the animal caretaker fed the dogs for a few days (an ontogenically acquired functional relationship). In fact the acquired behavior even persisted for a short time after the caretaker was no longer the person feeding the dogs. The experience of being fed by the animal caretaker had fundamentally changed the dogs in some semi-permanent fashion and that behavior could not possibly be an inborn instinct.

Early attempts to characterize ontogenically acquired adaptive behavior were internalistic and were generally either mentalistic, cognitive, or physiological. Few led to productive theorizing because they didn't provide for empirical analysis of the environmental conditions that control behavior. It was the documentation of the systematic changes in behavior as the result of specific changes in the environment that made Pavlov and Thorndike revered scientists.

The behavior analytic approach to short time scale adaptive behavior is to conceptualize the functional relationship as the semi-permanent equilibration of a behavior to its changed context. That equilibration results from the addition of a correlation between antecedent events such as stimuli or behaviors and subsequent events such as food presentation or shock (i.e. schedule of reinforcement).

As an example, a contingency could be implemented such that pecks to a green key would be reinforced, while no other behavior would be followed by food. At first, before the contingency is implemented (position labeled 1 on the x-axis of

Figure 4.16 the pigeon would simply stand there. After the contingency is implemented (the rise in the independent variable line) the pigeon comes to reliably peck the key across the seconds to days time scale. The behavior of the pigeon is said to have adapted to, or come into equilibrium with, the schedule of reinforcement (middle portion of Figure 4.16 labeled 2 on the x-axis). When the contingency is removed, the key pecking continues for a short time even though the conditions are identical to the initial conditions that did not control pecking. Eventually the pecking ceases, the behavior is said to extinguish, and the pigeon again just stands there (right portion of Figure 4.16 labeled 3 on the x-axis). This functional relationship could be labeled short time scale adaptation, behavioral equilibration, or learning.

This time scale of adaptation does not refer to a simple behavior such as salivating or pecking a green key but rather to the higher-order adaptation of behavior to the schedule of reinforcement (i.e., Thorndikian conditioning). The adaptation takes a short time to develop and it perseverates for a short time after the conditions are removed.

In sum, the behavior is a semi-permanent **c**hange in the **c**hange **i**n **b**ehavior (C(CIB)). In a computer metaphor, this adaptation is like a read write DVD (the output of the DVD can be changed but only slowly as compared to RAM but that change is relatively permanent).

Short time scale adaptation is characterized by:

(1) the ability of a stimulus difference to control a new response difference is semi-permanently changed for that individual
(2) An exemplar is a pigeon learning to peck on a green key
(3) Premise: A behavioral repertoire can be semi-permanently changed by exposure to environmental correlations (contingencies of reinforcement).
(4) Descriptive unit of analysis*:* "Learning" is a change in the behavioral repertoire associated with exposure to some nonrandom contingency in the environment. This behavior reverses with exposure to some contrary contingency
(5) hysteresis in seconds - days range – ca. 1 to 1000 trials
(6) the research area is also known as "learning"
(7) a typical research topic – matching
(8) Explanatory framework: Why did the organisms respond? It responded because of its reinforcement history. It learned to react that way.

a. Interesting Side Speculation

It would be interesting to determine whether the internal biological system that extracts invariant relationships from the environment (learning system) is essentially the same as the one that extracts invariant physical properties such as three-dimensionality from the environment (perceptual system). The similarity would not be a complete surprise in that it would be expected that the use of the

same biological system on successively more complex tasks would facilitate the evolutionary step.

3. Conceptual Coda: The Significance of Short time scale Adaptation and Why Behavior Analysis is Strongly Focused on it

Of all the dichotomies that can be placed on everything in the universe, the most important is animate versus inanimate. Of all the characteristics of life, the most important is the capacity of behavior to adapt or change to events in the environment across immediate, short, medium, and long time scales.

Behavior analysis is almost exclusively focused on the processes involved in an organism's adaptation across the seconds-to-days time scale to stimuli or behaviors correlated with important subsequent outcomes.

As a result of those correlations between antecedent events and subsequent outcomes, the functional properties of the behavior are changed in a fundamental and semi-permanent way. The details of those processes and resulting changes are outside the scope of this text but the main points are:

1. The reaction to a neutral stimulus changes over the course of a seconds-to-days time scale as a result of multiple exposures to a correlation between antecedent events and subsequent outcomes. Where stimulus *x* had resulted in behavior $\propto$; following the correlation trials, the same stimulus, *x,* results in behavior β. This change is illustrated in Figure 4.16 by the dependent variable being A at Time 1 when the contingency is not in effect and being B at Time 2 when the contingency is in effect. This capacity is well beyond most simple input output systems.

2. Further, the changed reaction to the originally neutral stimulus (stimulus *x*) continues to occur for a short time even after the contingency is removed. This is the meaning of the designation "a semi-permanent change." Stimulus *x* results in Behavior β for some time even when the conditions are identical to the original conditions when stimulus *x* had resulted in behavior $\propto$ and not behavior β. This is illustrated by the hysteresis of the dependent variable in Figure 4.16 following the removal of the contingency at Time 2.5. It can be seen that not only was the behavior changed by the procedure, it was changed in some semi-permanent way.

The ability to exhibit this short time scale adaptation was regarded so highly throughout history that it was millennia before humans were willing to accept that other animals could also exhibit this most significant type of adaptation (i.e., short time scale ontogenic adaptation).

The dog and trash can vignette given in the preface gave us an opportunity to contemplate the importance of short time scale adaptation. The first step in building an answer is: what real world arrangement of what real world events cause the dog to run, and which do not. This is, of course, exactly why Pavlov researched the amazing phenomenon of salivating to a caretaker. The second step is to develop a systematic paradigmatic explanation for the functional relationship, and a reliable approach to generalize our understanding.

4. Medium time scale Adaptation

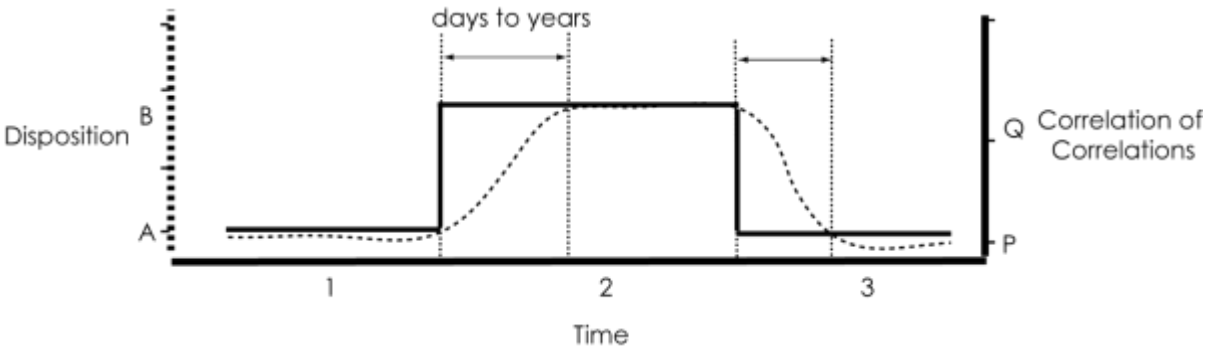


Figure 4.17 After an initial state of equilibrium between the independent variable and the dependent variable, the independent variable changes from State P to State Q. Following a lag in the days/years range the dependent variable changes to State B and comes into equilibrium with the new value of the independent variable. At some later time, the independent variable changes back to State P. This is followed by a lag in the days/years range of the dependent variable returning to State A and again coming into equilibrium with the independent variable.

The prototypical exemplar of medium time scale adaptation (Figure 4.17) is an individual coming to permanently react in a characteristic way to many situations: 1) one example would be response tendencies often labeled personality such as being shy or being mean; This class of adaptation would also include, 2) the residual effect of a behavior having been reinforced and then extinguished such as spontaneous recovery and the fact that re-establishing a formally reinforced behavior is much faster than the original acquisition; 3) A third exemplar is labeled learning to learn and is the faster and faster acquisition across exposure to a family of learning tasks; 4) A fourth class of this type of adaptation would include the behaviors often labeled as "automatic" such as driving a car, typing, riding a bicycle, or playing a musical instrument.

A familiar example of a relatively irreversible change in how the subject reacts to any one contingency is Piaget's shape/volume experiment. In it children were provided with a wide variety of examples of pouring a liquid from one kind of container to another (the commonality is the conservation of volume across shape). The child's response to the first exemplar was to "see" the shape change. The eventual medium time scale adaptation of the child was to "see" the conservation of volume.

It is critical to note that this time scale of adaptation refers to the emergence of an enduring characteristic higher order functional relationship rather than simple immediate time scale adaptation such as the expression of a specific behavior (salivation to food) or simple short time scale adaptation (conditioned salivation to a bell).

The fact is that the behavior of pecking a green key is not entirely removed by extinction. Spontaneous recovery is a medium time scale adaptation and is poorly conceptualized. This absence of understanding affects our ability to generalize functional relationships. For example, in order to correctly predict how long

discrimination training will take, it's necessary to be able to correctly predict across the variable labeled repeated experience and not be limited to predicting only the behavior of naive animals.

Unfortunately, the factors that control this time scale of adaptation have not been extensively researched and are not well understood. As a result, the causal factors in this time scale are more speculative than the other three time scales of adaptation.

The dependent variable for medium time scale adaptation is a virtually permanent change in behavior or the emergence of a "disposition." The independent variable for medium time scale adaptation is not entirely clear. It could be conceptualized as a residual or higher-order effect of short time scale adaptation, or it could be seen as the exposure of the organism to multiple contingencies in multiple contexts that all have a common aspect of the contingency. Finally, a correlation of the component contingencies of reinforcement may be seen as the active factor.

The measured behavior could be a change in the equilibrium established by short time scale adaptation as the result of commonalities of specific sub-relationships that extend across, are embedded within, or are shared by, multiple contingencies. For example, if each circle in Figure 4.18 below represents a contingency, then the left portion of the figure represents a single contingency that results in short time scale adaptation. The overlap in the three contingencies in the right portion of the figure represents the overlap or common aspect of three different contingencies (which taken together could be the cause of medium time scale adaptation). The point of the figure is that removing one circle (i.e., set of contingencies) from the right portion of the figure with extinction would not remove the conditioned effects of the remaining "versions" of the contingency. Interestingly enough, one of the dimensions of the reinforcement contingency could be purely adventitious rather than intentionally instantiated

Figure 4.18 The circle to the left represents a reinforcement contingency. The intersection of the three circles to the right indicated with an asterisk represents the shared aspects of three "different" reinforcement contingencies.

The independent variable in short time scale adaption can be conceptualized by a two-dimensional scatterplot representing the correlation between two variables such as the probability or time of occurrence of a stimulus (key light) or behavior (key peck) and the occurrence of a reinforcer (food presentation). The independent variable in medium time scale adaptation could be conceptualized as a three dimensional scatter plot representing two different events with the reinforcer. This relationship is illustrated in Figure 4.19.

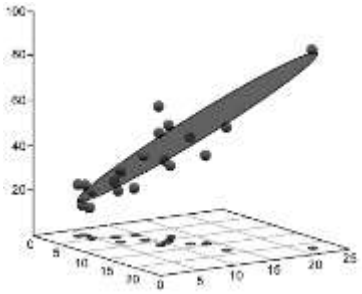


Figure 4.19 An illustration of multivariate covariance. For example, grades in a course are a function of both the amount of studying and the prior grade point average

It has been pointed out that the correlation between events in Thorndikian and Pavlovian conditioning procedures resulted in the higher order behavior change labeled "conditioning" across evolutionary time by utilizing information which enabled optimization of behavior. A similar argument could be made with respect to medium time scale adaptation. The correlation of correlations could lead to medium time scale adaptation across evolutionary time as the result of its ability to optimize behavior via contingencies in the environment.

It should be obvious that single subject designs used to prove causation in short time scale adaptation (recover baseline within same subject) may not be appropriate for medium time scale adaptation. For example, if we wish to study the acquisition of bicycle riding we may never be able to recover baseline within that same individual. Multiple baseline procedures are often used to study medium time scale adaptation for that reason.

Recall the "change of change" description for time scale of adaptation. A reaction to a green light going on and off or immediate time scale adaptation is labeled a change in behavior (CIB). A learned behavior to the green light going on such as a change from pecking a red light going on to not pecking the red light, but rather pecking the green light going on is a change in that functional relationship or short time scale adaptation. This could be designated as a C(CIB). In the medium time scale adaptation case, the learned change in behavior itself is changed. For example, whereas it had originally taken 100 trials to learn to peck green rather than red, it now only takes one trial to learn to reverse the color that is pecked. This is a change in the change in the original reaction or C[C(CIB)].

In a computer disk metaphor, this adaptation is like a writable DVD. These DVDs can be written on once but after that they can not be changed.

Medium time scale adaptation is characterized by

(1) the ability of a stimulus difference to control a response difference is altered for the individual for virtually the rest of the organism's life
(2) an exemplar is someone developing a personality
(3) Premise: A behavioral repertoire can be virtually permanently changed in an individual by exposure to multiple correlations with a shared contingency.
(4) Descriptive unit of analysis: “Disposition,” is a virtually permanent

characteristic way of responding in the behavior of an individual organism attributable to a common functional relationship embedded in many different relationships. This change is virtually life-long but does not affect the genetic code.

(5) hysteresis in days - years range
(6) the research area is also known as "developmental psychology"
(7) a typical research topic – personality
(8) Explanatory framework: Why did the organism behave that way? Because it had been exposed to commonalities in environmental conditions or commonality of embedded relationships that made the behavior develop that way across the individual's life span. "The organism had developed a disposition to react that way."

5. Conceptual Precursor: Evolution

Darwin realized that the astonishing diversity of life forms could be accounted for by nothing more than variation and the inescapable natural contingency of differential reproductive success.

Evolution refers to the change in the relative frequency of individual organisms possessing a particular characteristic in the population. If a particular version of a trait reproduces more than alternatives, then the population will necessarily come to have more of those individuals than the alternative. The proportion in the population will continue to increase until the entire population possesses that trait.

It's important to note that evolutionary selection must be through the selection of genetic material and that the selective pressure must extend across individuals and generations. Evolution is not a parent passing on to its offspring what that parent learned across its life span. Parents that have learned English do not produce children who are born speaking English when brought up by a Chinese family living in China. Rather, the mechanism of change is a function of the relative reproductive rate of individuals with particular genetic characteristics.

For example, a peck to a red key contingency for one pigeon at one time in that individual's life will not result in an instinct to peck red in all pigeons. But, if half of the entire population of pigeons spontaneously peck a red light and only they live to reproduce then only red light peckers will exist in the next generation. The effect is similar with less extreme proportions.

It is important to note at this point that the behavior becomes "optimized" to the enduring past contingencies, not momentary contingencies nor future contingencies. Optimization is to be seen as the best option of those available, not something perfect or without flaws. Secondly, the change is a change in the frequency of individuals behaving in a particular way within a population not a change in the behavior of a specific individual. Thirdly, the evolution of more and more adaptive behaviors may not be sufficient to surmount the challenge and the species may die off anyway.

If a more extreme aspect of some trait reproduces more than alternative forms for any reason, then the better reproducing form will come to predominate (i.e., it

is said to be more “fit”). Successively more extreme versions may even change from the original population enough to create a new species (i.e., speciation). Additionally, the new species may even drive the original population into extinction because the new species can exploit the original niche better than the original species (e.g., it may eat faster and consume all the available food) or because that more extreme version may be better able to survive habitat loss (e.g., it may prosper in what is left of a rainforest when all the trees are gone). “Survival of the fittest" should not be taken to mean the most vicious or aggressive or strongest survive. For example, domestic cats are not the most vicious, aggressive, or strongest felines, but they are probably the felines most likely to exist for the next thousand years because they entered a niche where humans take care of them and those cats are optimized to do extremely well in that niche. If they do survive better than wild cats, then they would be the fittest. They would be fittest for the existing conditions of earth.

Evolution by natural selection is inevitable. Metaphors for evolution abound. The process can be easily illustrated. Suppose you choose a hand of four cards from a well-shuffled deck. If you then draw one card at a time and save your four best or fittest cards and discard your lowest or weakest card, you will inevitably end up with the best four cards in the deck. In fact, the specification for what is the best four cards can change. If you save the new best and continue to draw from the deck over and over you will end up with the best four cards according to the new classification.

Alternatively, water flows downhill. If you put ten consecutive bags, each with a hidden hole in it, over a leaking bag of water, the water in the innermost bag will find its way to the floor. In fact, you could put 10,000 bags or 10 million bags, each with a hidden hole in it, over a leaking bag. Eventually and inevitably the water would successfully “find” its way through the almost infinitely complex maze. This does not mean that water has a mind or that it is being controlled by the space aliens. Water is following a very simple natural law. Molecules move downhill; that is to say, the population of water appearing on the downhill side of a hole “reproduces more” than the water molecules which are on the uphill side of the hole. The result of this process is that water ends up on the floor, just as evolution enabled DNA to “find” a path to millions of niches.

A third metaphor for how evolution leads to a new species displacing an old species, or a new behavior displacing the old behavior is the spread of cultures. If one culture landed on North America in the 1600s with guns and very virulent diseases for which the invaders were resistant, and a total contempt for any culture but their own, what could you predict would happen in less than 500 years? The invading culture would experience relative reproductive success. That new invading culture would own everything. The original existing indigenous culture would be annihilated. Make your own decision as to whether it is good or bad, but in either case, it’s to be expected.

Evolution is a fact. If you want to be a behavior analyst and are one of the few small sects of people who don’t believe in evolution, take a few biology courses and geology courses so that you can be exposed to the overwhelming body of evidence and proof for evolution. Keep in mind that if you don’t want to believe in evolution

simply because “it was only one person’s opinion,” or “there is simply not enough proof for evolution;” then it is incumbent upon you to compare the amount of evidence for your belief with the amount of evidence for evolution through natural selection. If you are unsatisfied with the 10-minute review provided in the present text, then expose yourself to the 100, 10,000, or 10 million pages of proof for evolution through natural selection that is available for the asking. When you discover that there is vastly more proof for evolution than any other view (including yours), then you must accept that you are hoisted by your own petard. There is no controversy in science concerning whether the complexity in a life form is the result of successive changes in the complexity of different life forms as the result of natural contingencies (i.e., evolution).

6. Long time scale Adaptation

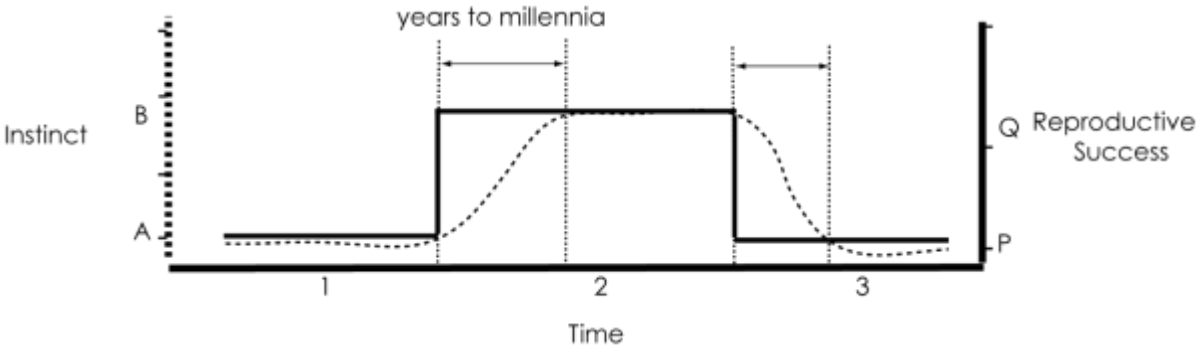


Figure 4.20 After an initial state of equilibrium between the independent variable and the dependent variable, the independent variable changes from State P to State Q. Following a lag in the years/millennia range the dependent variable changes to State B and comes into equilibrium with the new value of the independent variable. At some later time, the independent variable changes back to State P. This is followed by a lag in the years/ millennia range of the dependent variable returning to State A and again coming into equilibrium with the independent variable.

The exemplar of long time scale adaptation (Figure 4.20) is a species acquiring (evolving) the reflex of salivating to food. The measured behavior is a change in or emergence of the behavior difference to a stimulus difference for the species as a whole as the result of differential reproductive success for that new functional relationship (rather than ontogenetic experience). The reflex of salivating to food (i.e., an unconditioned reflex) evolved or emerged across many generations. This change is across populations across generations not within an individual. It is an evolved functional relationship or instinct. It is the emergence of this adaptation throughout the population that defines this time scale **not** the expression of the behavior in an individual.

The IV is a change in the reproductive success of some behavior for the species. The DV is a change in the adaptation or functional relationship in virtually every member of the entire population. For example, animals that salivated to food reproduced more than animals that swallowed food without salivating. Alternatively, in the case of domestication, if only animals that are friendly from birth are able to reproduce then a friendly species is created. The DV is a change in or emergence of the exhibition of "friendly" behavior from birth in the population of animals.

It is critical to keep in mind that this time scale of adaptation refers to the emergence of the innate behavior as the result of reproductive success rather than the simple expression of some previously acquired instinct such as salivation to food in the mouth. Admittedly, research on factors that cause the emergence of an instinct is likely to take a long time.

Salivation is an immediate time scale adaptation to food in the mouth. The act of salivation itself could be an acquired response of a species as the result of the reproductive success of salivating to meat in the mouth (an unconditioned response), or salivation could be a learned response in an individual as the result of a reinforcement contingency for that individual (a conditioned response)

The "correct" or "better" response to a particular environmental condition must be stable across generations and have a reproductive impact to evolve. This behavioral adaptation often takes a very long time to evolve because, most typically, many generations are necessary to install its various components into the gene pool such that it will breed successfully and breed true in all individuals of the population. It should be noted that an instinctive behavior may predate the species that expresses it. As a result, the point of origin for the earliest elements of a particular instinct may be quite old. What is now labeled salivation to food in the mouth could predate digestive saliva and a mouth.

Research could document the change in the frequency of a trait in a species as a function of selective breeding for that trait.

This behavior change can be seen as broader than the change measured as a medium time scale adaptation. In that sense, it can be seen as a change in the change in the change in a reaction to a stimulus. Long time scale adaptation is C{C[C(CIB)]}.

In a computer metaphor, this adaptation is like a DVD (it comes prerecorded, but it can be read many times). It is important to note that as it is with the data on a DVD, instincts have an origin and that origin is in the natural world.

Long time scale adaptation is characterized by:

(1) the ability of a stimulus difference to control a response difference is altered for the species or subspecies
(2) an exemplar is a species evolving the reflex of salivating to food
(3) Premise*:* Differential reproductive success can establish a behavior difference to a stimulus difference for virtually every member of the species
(4) Descriptive unit of analysis: "Instinct," which is a change in the behavior to a particular stimulus change which is attributable to differential reproductive success.
(5) hysteresis in years to millennia (actually generations)
(6) the research area is also known as animal behavior, ethology or comparative psychology
(7) a typical research topic – migration
(8) Explanatory reference: Why did the organisms behave that way? Because its ancestors that did, obtained differential reproductive success (or "because it is an instinct").

7. Conceptual Follow-Up: What Aspects of Behavior Can Evolve?

There are different entities whose frequency in the population can be changed by differential reproductive success.

a. Evolution of Behavior Versus Structure

The interest of the present text is on behavior rather than on biological structures. Unfortunately, the vast majority of examples of evolution concern

structures. However, the evolution of behaviors proceeds exactly like the evolution of structures. Given variation in the details of some functional relationships involving some behavior to the environment, if more and more extreme versions of the functional relationship provide greater and greater reproductive success, then the typical behavior of the species to that stimulus will shift in the more successful direction until there is no more reproductive advantage. The eventual result will be that virtually every individual in the species will possess the "more successful adaptive behavior" to that environmental event (e.g., fleeing from a predator rather than approaching it).

b. Evolution of the Time Scale of Adaptation

Various behavioral adaptations to environmental contingencies equilibriate to their most appropriate time scale of adaptation. For example, the reaction to bright light is a pupillary contraction. That is to say, the immediate time scale adaptation itself came to be or emerged via evolution (long time scale adaptation). On the other hand, the reaction to key pecks to red being followed by food but key pecks to green not being followed by food in an individual, results in the organism learning to peck red (short time scale adaptation).

The different time scales of these two adaptations have as much adaptive significance as the target of migration. Very little flexibility is needed when "deciding" what to do to bright light in the eye; bright light always causes retinal damage. The damaging effect occurs across individuals and in every generations. As a result of its devastating impact on reproductive success, the functional relationship of pupillary contraction to bright light comes to be universal in the population, because any organisms that didn't react that way had much worse vision and died sooner and had fewer offspring. On the other hand, substantial ontogenetic information is necessary to "decide" what to do when a red light comes on. Little, with respect to what to do when a red light comes on, can be "pre-learned" before the organism is born because in a particular organism's future, it may be a red light that signals food or it may be a green light that signals food, or something altogether different that signals a response-food contingency. As a result, organisms that can learn to peck but do not peck red unconditionally from birth are more efficient on expending their energy and therefore live longer and have more offspring than those that peck red unconditionally or that cannot learn to peck red under any condition.

c. Evolution of the Components of the Functional Relationship

First, various components of the functional relationship (for example, the releasing stimulus or destination of migration) can change as the result of evolutionary selection. The adaptive significance of the ability to adjust behavior in this way is obvious. For example, a different destination of migration could have fewer predators. In particular, imagine a population of Alaskan birds that migrate to the southern tip of South America with a number of pairs off to the east where there is an island. Imagine further that the tip of South America becomes overrun

with shipwrecked rats that eat eggs. Soon the remaining population of birds would be mostly east flying birds with only a few to the tip of South America because those that nested on the tip of South America had very few surviving offspring.

It would be easy to envision examples where the evolutionary change is in the behavior (e. g., fly versus swim), the stimulus control (e, g., approach the island or the mainland), or the timing (e. g., migrate in summer or winter).

8. Conceptual Speculation: Potential Mechanism That Could Increase the Efficiency of Genetic Selection

Short time scale adaptation or learning is the establishment of a functional relationship within the life span of an individual organism that results in what could be labeled a functionally significent outcome. This effect is illustrated by a hungry organism coming to peck a green key which is reliably followed by food, or salivating to a bell which reliably precedes the presentation of dry meat powder in the mouth.

It has been noted that: 1) **if** the machinery underlying learning some functional relationship is related in some way to the machinery underlying the genetic expression of that functional relationship, and 2) **if** speed of learning that functional relationship **is** related to how similar that learning is to the actual genetic expression of that functional relationship. 3) then this connection between short and long time scale adaptation would dramatically simplify the establishment of functional relationships as instincts (the Baldwin effect - Staddon).

The logic being: any functional relationship that could be learned would have individuals that learn it faster or slower; faster learning could result in greater reproductive success. **If** so, then the populations would shift to being made up of faster and faster learners. That would also mean that the population would be made up of individuals closer and closer to having the functional relationship expressed as an instinct. Eventually the process, recursively implemented, would result in the entire population having the functional relationship as an instinct.

It is essential to note at this point that this is not to suggest that a short time scale adaption can be passed on from parent to offspring. It suggests that if the learning speed of some functional relationship provides relative reproductive success across the population, then eventually the entire population will come to have that trait as an instinct if learning speed more closely approximates an instinct. Additionally, challenges that can no longer be successfully solved with the same instinct will come to append ontogenically established adaptations which add or subtract components to the basic functional relationship. For example, the removal process could occur first through the selection of the ability to quickly learn to counteract the instinctive behavior, then through the incomplete expression of the instinct, and eventually through the absence of the instinct altogether.

This ability to select individuals from a population based on intermediate forms of each time scale of adaptation could dramatically simplify the

development of the optimum time scale of adaptation for each challenge posed by the environment and dramatically simplify the task of establishing or removing a functional relationship from the population.

As alluring as this possibility is, it is essential to keep in mind that the Baldwin effect is speculative.

C. Conceptual Follow-up: Divergent Example of Time Scale of Adaptation

These conceptual categories of time scales (immediate, short, medium, and long) do not exist in isolation. All time scales are in effect simultaneously.

This simultaneity can be illustrated by returning to the television example used in the level of molarity section:

Re: Immediate time scale adaptation. The television behaves in the context of environmental events. It receives signals and presents a picture (just as a person might hear words and answer a question). The TV changes with changes in the broadcast signal (just as a person will answer differently depending on the question). The television exhibits immediate time scale adaptation.

Re: Short time scale adaptation. The TV also changes in a semi-permanent fashion as the result of changes made to its control knobs. That change is easily reversed and does not affect future models of the television. How the TV changes as the result of environmental events can be reversibly changed. The channel and volume can be set (the viewer can change them and change them back). The television exhibits short time scale adaptation.

Re: Medium time scale adaptation. Televisions can be set up via the set-up menu by the viewer to display no sports channels or display with a specific aspect ratio or receive PAL signals rather than NTSC signals (just as a person can develop a personality). The television exhibits medium time scale adaptation. These changes in the TV are typically constant for the life of that particular TV.

Re: Long time scale adaptation. Additionally, TV sets, as a population have come to behave differently even before they get any input from their end users TV sets have evolved to LCD flat panels with better resolution and sharper colors just as humans have evolved from simpler forms to our current form. The television exhibits long time scale adaptation.

It should be self-evident that the behavior of either a person or a TV is a combination of factors operating at different time scales and at both more molar and more molecular levels. Alterations across any time scale or any level of molarity of either a television set or of a person can have effects on that system.

D. Conceptual Follow-up: Comparative Analysis of Time Scales

Comparative Analysis: Time Scales of Adaptation

	Immediate-term	**Short-term**	**Medium-term**	**Long-term**
Global Question	Why do organisms **react?**	Why do organisms **learn?**	Why do organisms develop **dispositions?**	Why do organisms develop **instincts?**
Descriptive Unit of Analysis	**Reaction** ***Change*** in behavior of individual	**Learning** ***Semi-permanent change*** in behavior of individual	**Disposition** ***Virtually permanent change*** in behavior of individual	**Instinct** ***Permanent change*** in behavior of virtually all members of a species
Causal Perspective	Reactions are caused by **stimulus change**	Learning is caused by **non-random relationships in the environment**	Dispositions are caused by **commonalties in reinforcement contingencies**	Instincts are caused by **non-random reproductive success**
Explanatory Reference	Why did the organism respond? Because the **stimulus changed**	Why did the organism respond? Because of its **reinforcement history**	Why did the organism respond? Because the **commonalities in its reinforcement contingencies**	Why did the organism respond? Because of the species **reproduction contingency**
Research Task Enumerate functional relationships between IV and DV	Of what are **reactions** a function of? i.e., the **expression** of a functional relationship	Of what is **learning** a function of? i.e., the **emergence** of a functional relationship	Of what are **dispositions** a function of? i.e., the **emergence** of a functional relationship	Of what are **instincts** a function of? i.e., the **emergence** of a functional relationship
Example IV	Adjust intensity of stimulus	Follow pecks with food or with dirt	Follow many behaviors with consequences with shared contingencies	Allow only left-turning flies to breed
Example DV	Measure change in organism's behavior **(reaction)**	Measure semi-permanent change in organism's behavior **(learning)**	Measure change in permanence of an organism's behavior **(disposition)**	Measure change in behavior of subsequent generations **(instinct)**

V. Spatial Representation of Behavioral Equilibrium Across Time and Unit Domains

A. Spherical Representation of Levels of Molarity and Time Scale

The two major dimensions of adaptation (level of molarity and time scale of adaptation) can be represented with the radius and the position on the surface at that radius respectively. This conceptualization was implied in Figures 4.13 and 4.14.

1. Level of Molarity as the Surface of a Three-Dimensional Radius

Measures can be more or less molar. Distance from the center of a sphere could conveniently represent molarity of measurement.

Figure 4.21 The concentric circles depict concentric layers of a sphere (like an onion) and represent the successively more molecular levels of molarity in behavioral adaptation.

More molecular variables are depicted toward the center and more molar variables more distant from the center. Successive layers of the "onion" represent specific molarities of paradigmatic context (e.g., cellular, organismic, group, etc.). The conceptualization of the molarity dimension conveniently depicts that physiological or cellular variables underlie all behavior and that ultimately chemical, and in turn, quantal mechanisms mediate all behavior change. A weakness of this metaphor is that it is possible to infer that only one individual lies within the group level and only one cell lies within the organism level, etc. (this is the flaw noted in Figure 4.14). In actuality, it is a class of relationships that are indicated by each layer not individual elements (as is better indicated in Figure 4.13).

An internal explanation, or an explanation which appeals to a lower paradigmatic context would be seen as appealing to processes within an inner sphere for an explanation with this spherical model. With this model, external explanations would be seen as appealing to factors on the same surface at the same level as the original question, while an explanation appealing to a higher level of molarity or a contextual explanation would appeal to the next higher sphere for explanation.

2. Time Scale as an Area on a Spherical Surface

The behavior change of interest can be across any of the four time scales. Points on the surface of the molecular sphere at a particular level of molarity could

be used to represent the time scale dimension for that level of molarity. For example, the surface of the sphere at the level of behavioral adaptation could depict time scale of reversibility of behavioral phenomena (Figure 4.22).

Figure 4.22 The four time scales of adaptation can be represented by four segments of the surface of a sphere. The triangle on the left depicts the four time scales at any given level of molarity (as depicted on a pyramid when flattened out into a triangle). The image on the right is the image of a sphere with four equal quadrants mapped onto its surface. Each quadrant depicts one of the four categories of time scale of adaptation.

The surface could be partitioned into four equal quadrants, like the four sides of a pyramid mapped onto a sphere (imagine a pyramid tin can exploded out). The left frame of Figure 4.22 shows the covering of the pyramid flattened out.) The right frame shows a spherical view. This spherical representation provides all time scales as contiguous with the potential of directly interacting. For example, a functional relationship such as discrimination would be depicted on the surface labeled "short" and could be potentially changed by changing any of the other three time scales, just as topologically changing Cartesian space changes a form drawn on that space. A figure drawn on a rubber sheet changes as the sides of the sheet are distorted or changed by pulling. An advantage of a spherical surface metaphor is that it provides orthogonal axes all of which could be continuous and any of which could affect a relationship on any other. A disadvantage of a spherical surface metaphor is that it fails to portray that short, medium, and long time scale effects are all instantiated by the expression of an immediate time scale effect.

It is important to reiterate that these unit-domain and time-scale categories do not exist in isolation. A behaving pigeon is alive, is chemicals, is matter, and has an evolutionary, a developmental, a reinforcement, and a perceptual context. These multiple coexisting determinants are analogous to the multiple determinants of a symphony, pizza, or bank account.

In point of fact, these category boundaries are actually a matter of pedagogical convenience or “scaffolding.” There is no sharp demarcation between classes of functional relationships. There is no real reason to maintain a hard distinction between “slow” perceptual adaptation and “fast” learning adaptation. On the contrary, there is every reason to examine manipulations typically reserved for one-time scale by other research areas.

B. Factorial Representation of Molarities and Time Scales

A structure within which to view nature results if we combine the two dimensions of science (Figure 4.23).

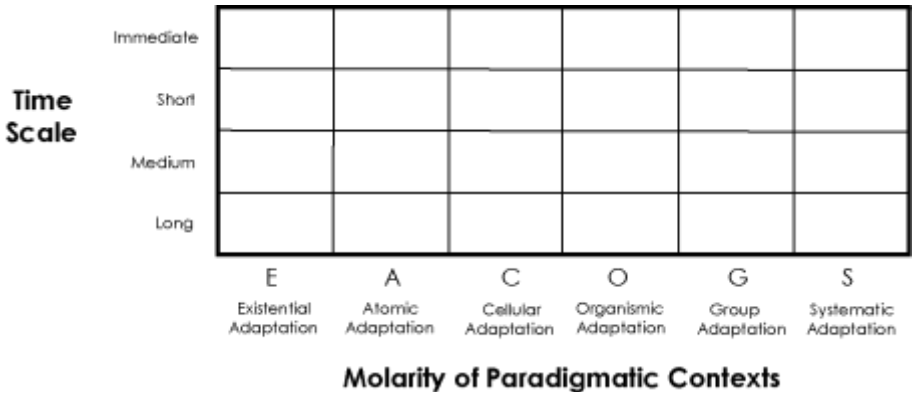


Figure 4.23 A structure providing a representation of how the various levels of molarity and time scales fit together as a whole. Each small box would depict one specific level of molarity (e.g., organismic adaptation) at one time scale (e.g., short time scale adaptation).

VI. Conceptual Follow-Up: Direct and Indirect Assessment of the Adaptation of Behavior

A. The Emergence, Acquisition, or Origin of Adaptation to a Change in Conditions (Direct Assessment)

This is the procedure used to define time scales of adaptation. It is the direct and most obvious method of assessing adaptation to some changed procedure.

The emergence measure illustrated in Figure 4.24 is the transition from some stimulus condition and its controlled behavior (a functional relationship) under one procedure considered a baseline or zero state, to some asymptotic performance to a different procedure (a different functional relationship), and back to the baseline again. The difference in the functional relationships is attributed to the difference in the procedures from the baseline to the treatment. The emergence of the new functional relationship is an x-axis measure as well as a y-axis measure. It is documenting the resulting change in stimulus control with increasing experience with that different procedure (i.e., *y*-axis change as a function of *x*-axis change).

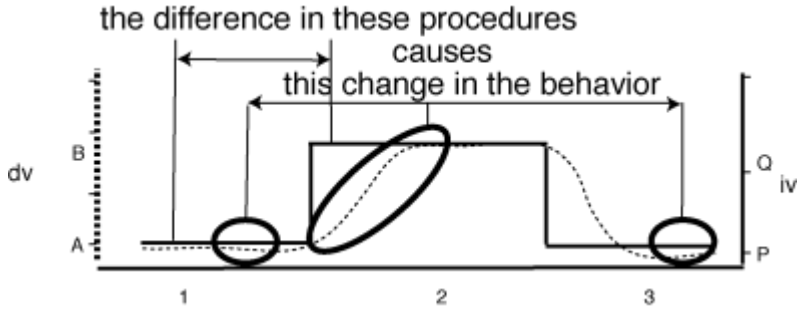


Figure 4.24 This figure depicts the emergence or acquisition in a dependent variable (dotted line) as a function of a change in the independent variable (solid line). In sum, the change or difference in the dependent measure is caused by the difference in the independent variable. The initial state of behavior (in the absence of the treatment) is seen to be recovered at Time 3 when the independent variable is removed.

Given that adaptation of a functional relationship as a function of experience is a change in a response class as a function of a stimulus class, then there are two potential targets of the change.

1. Emergence of the Topographical Characteristics of the Behavior

The reaction itself could be the focus of interest, for example reinforcement could be dependent on a key peck but not an undirected head motion. Alternatively, string pulls or turning circles could be the dependent variable.

2. Emergence of the Stimulus Control Over the Behavior

The stimulus controlling the behavior could be the focus of interest. For example, pecks to a green key could be reinforced but not pecks to a red key. Other stimulus conditions could be time, prior response count, or even the variability of the response requirement.

B. Comparison of the Asymptotic Expressions of Adaptation in Two Different Situations (Indirect Assessment)

The second approach to assess the adaptation of an organism's behavior is based on the observation and documentation of the expression or the equilibrium of the asymptotic behavior. This is when asymptotic behavior under one procedure is subsequently compared to the equilibrium behavior maintained by a different procedure as is illustrated in Figure 4.25. It is then assumed that the difference in the behavior resulted from the difference in the procedures. It is almost always an entirely y-axis measure, and is typically (but not necessarily correctly) presumed to be immune to any prior history. This comparison in asymptotic performance is typically between two specific procedures rather than between a procedure and what could be considered a baseline, although baseline to treatment is a comparison of two procedures. For example, learning could be studied by documenting a reaction or the asymptotic expression of a behavior (immediate time scale adaptation) under two different conditions such as fixed-interval and fixed-ratio schedules and inferring that the difference in those reactions was due to the difference in the contingencies of reinforcement.

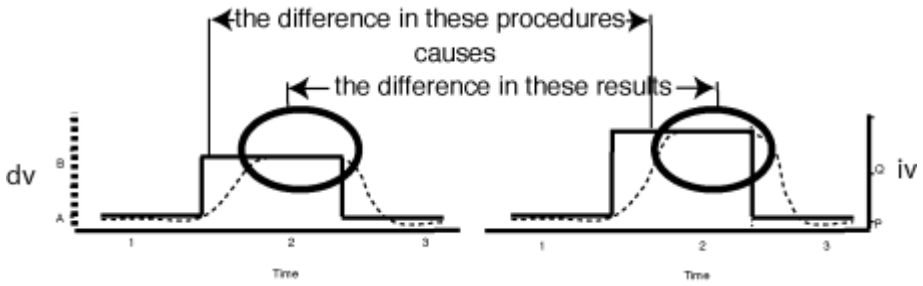


Figure 4.25 This figure depicts the difference in the asymptotic expression or performance of a dependent variable (dotted line) as a function of a difference in the independent variable (solid line). In sum, the difference in the dependent variable is caused by the difference in the independent variable.

Chapter 5
Knowledge

I. Conceptual Precursor: What is Knowledge?

A. The referent for knowledge
B. What does it mean to have knowledge of something
C. Epistemological boundary of knowledge
D. The vehicle of knowledge

II. Conceptual Precursor: Dynamics and Equilibrium

A. Dynamics
    1. conceptual precursor: determinants of behavioral variability
        a. the assumption of intrinsic variability (no cause)
            i. outside organism
            ii. inside organism
        b. the assumption of strict determinism or extrinsic variability (due to cause)
            i. outside organism
            ii. inside organism
    2. three types of behavior change or behavioral dynamics
        a. simple dynamics
            i. bitonic simple dynamics
            ii. monotonic simple dynamics
            iii. entrained simple dynamics
        b. synchronous dynamics or average dynamics
        c. asynchronous dynamics
B. Equilibrium
    1. three types of behavioral stability or behavioral equilibrium
        a. neutral equilibrium
        b. stable equilibrium
        c. entrained equilibrium
C. Conceptual follow-up: dynamics and equilibrium

III. Conceptual Precursor: Variance and Covariance

A. Variance
B. Covariance
    1. covariance with dichotomous predictor and dichotomous predicted
    2. covariance with continuous predictor and continuous predicted
        a. continuous predictor (X)
        b. continuous predicted (Y)

c. illustration: covariance with continuous degrees and types of relationships between X and Y

3. multivariate covariance
   a. number of predictor variables
      i. one (univariate)
      ii. more than one (multivariate)
   b. number of predicted variables
      i. one (univariate)
      ii. more than one (multivariate)

IV. Knowledge is Behavior Controlled by Covariance

A. Conceptual precursor: Covariance as accountable variance
B. Example of understanding behavior change by understanding multiple sources of variance
   1. conceptual aside
C. Interpretations of accountable variance
   1. cause effect interpretations
   2. description only interpretations
D. Potential reaction strategies to residual variance, error, or ignorance
   1. experimental solution
   2. withheld judgment
   3. assumption of "true score" and random error
   4. delegation of the problem of residual variance
      a. acceptable delegation
      b. unacceptable delegation
   5. assumption of nonlinear dynamics (chaos)

V. Conceptual Follow-Up: The Task of Research is to Find and Understand Covariance

CHAPTER 5

Knowledge

After discussing our professional goals (i.e., that we want to be ethical and prosperous), we determined that a clear "understanding" of the "truth" would best provide us with what we wanted. We also came to realize that that was also the very characterization of the products of science. It therefore followed that we must be scientific in our practice of psychology (i.e., behavior analysis) if we are to get what we want as a career goal. Next we began our development of a more complete understanding of science (or to better "see" the dolphin) by reviewing a variety of ways to conceptualize science and detailing its basic methodology. Finally, we examined the context of psychology and its specialty areas by conceptualizing where psychology and behavior analysis fit within all human endeavors and within the fields of science in particular.

The next six chapters will examine the products of science.

In this chapter, we will first identify the problem to which science addresses itself (variance in nature). We will then address the nature of the results of the questions that science asks of the natural world. We will see that we are interested in understanding the relationships between observations, that is, how one variable changes as a function of some other variable, because that information is the only information which will allow us to reliably predict, control, synthesize, describe, and explain nature.

In order to stay focused on the empirical relationship between empirical events, we will need to understand the actual referent for the term knowledge so we are not confused and side tracked by its many manifestations.

One of the most important and revolutionary aspects of the behavior analytic paradigm is its exclusive focus on the relationship between the observable external functional properties of its objects of interest.

I. Conceptual Precursor: What is Knowledge?

A. The Referent for Knowledge

All behavior analytic referents are either external empirical entities or the external empirical relationship between empirical entities (i.e., functional relationships). The correct conceptualization of the topic of this chapter well illustrates that the results of the questions asked by science of nature are empirical relationships between empirical observations. Recall the anecdote about the appropriate conceptualization of the cause of egg retrieval in the gull.

When an organism's behavior comes under the control of a functional relationship it is labeled knowledge. The behavior is not caused by knowledge. The significance of the conceptualization of "knowledge as behavior under the control

of covariance in the environment" cannot be overstated. To reiterate for emphasis,

> BEHAVIOR UNDER THE CONTROL OF COVARIANCE IN NATURE IS **LABELED** KNOWLEDGE, THE BEHAVIOR IS **NOT** **CAUSED** BY KNOWLEDGE.

Figure 5.1 illustrates the incorrect internal versus correct external referents for the meaning of knowledge. The inferior perspective of knowledge on the left emphasizes that knowledge is thought of as a thing located in the mind (i.e., the referent for knowledge is a thing inside a head). Behavior analysis considers the mind, its contents, and processes as meaningless. The meaning of any word that refers to something in the mind is meaningless because there would be no way to prove anything about the mental entity one way or the other. This unproductive internal non-empirical perspective is a source of persistent and debilitating confusion about what knowledge is, and is an impediment to understanding behavior. This debilitating effect is well illustrated by the statement that behavior is caused by knowledge.

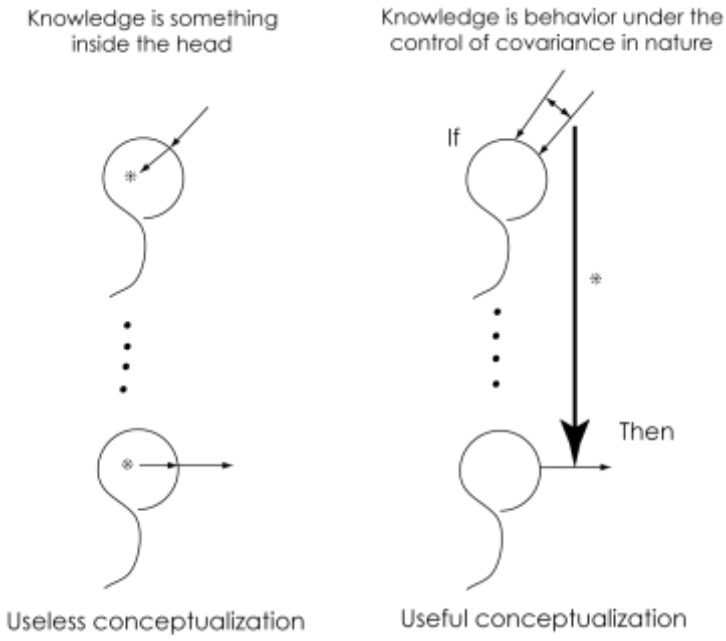


Figure 5.1 The left portion of the figure illustrates a common conceptualization of knowledge by the lay public with an asterisk, i.e., it is something inside the head. Information goes into the mind and then information comes back out. The right portion of the figure illustrates the behavior analytic conceptualization of knowledge with an asterisk, i.e., it is a behavior under the control of covariance in nature. Behavior analysis passes over in silence anything that may or may not be inside the organism.

The behavior analytic or radical behaviorism conceptualization of knowledge is illustrated on the right side of Figure 5.1. In it knowledge is portrayed as behavior under the control of covariance in nature not a piece of meat or an as yet unknown and unprovable activity in the brain as is illustrated on the left side of the figure.

Oddly enough, the empirical behavior analytic referent for knowledge

illustrated on the right side of the figure is more difficult for some to grasp than invoking the activities of the non-empirical mind with undefined properties.

It is like the ease with which even ignorant people can quickly grasp the notion that an invisible dragon carries the sun across the sky, while it is very difficult to explain the actual celestial mechanics causing the sun to appear to move across the sky even to college students. As a result, even though the behavior analytic referent for knowledge is factual and is much more useful, it is not as popular in the common culture as the "mind." The inescapable fact is, made-up metaphysics does not, and cannot, provide any answers. An appeal to the unknowable or the incomprehensible is by definition useless at best and debilitating for most.

Similarly, claiming an explanation is located in an imaginary cognitive processing center is also pointless. For instance, claiming that human play behavior comes from a play center in the brain is a tautology that robs Peter to pay Paul and shouldn't satisfy anyone's curiosity. To say play behavior comes from the play center simply changes the question from what causes play behavior in the child to what activates the internal play center? In the absence of the environmental cause of the play center activity, the "explanation" for external play behavior is totally meaningless. The environmental causes of the activity in the play center in the brain are necessary if the explanation is to be useful; and even if the environmental causes of activity in the play center could be identified, the play center in the brain itself remains an irrelevancy. It is more parsimonious to simply state that the environment causes play behavior. The logic being: if B causes C, and A causes B, then A causes C.

Occasionally someone will assert (incorrectly) that an internal construct such as the play center in the brain is necessary because several things control the activity level in the play center. For example, it could be said that the presence of a bully may inhibit the play center and the presence of toys activates the play center. Behavior analysts would say that that may or may not be true, but the appropriate conceptualization is that play activity tends not to occur in the presence of a bully but does tend to occur in the presence of toys. Nothing whatsoever is lost by an external conceptualization because nothing whatsoever had been actually added by the internal tautologies.

B. What Does it Mean to Have Knowledge of Something?

What is it to understand the true facts of nature? We want to correctly describe, predict, control, synthesize, and explain nature. Our verbal behavior must be under the control of actual covariance in nature and not imagined covariance. In order to describe some element in nature, we must correctly specify the characteristics of how that thing interacts with other elements in nature (e.g., its color, or the fact that it dissolves in water). In order to predict nature, we must know something that will reliably warn us, or give us notice of an upcoming change in our variable of interest. In order to control nature, we must know those variables that reliably modulate, or which are necessary or sufficient to change our variable of interest. We can synthesize something only when we understand how precursors can be combined to produce some desired change or event. Finally,

we can explain nature only when we can specify the general class of functional relationships which are the general case of the specific changes we observe and then specify how those particular changes fit within a larger and integrated paradigm. Paradigms provide the formal system within which predictions can be made and the principles by which generalizations can be made.

C. Epistemological Boundary of Knowledge

When we want to know how to correctly understand our environment, we look to the natural world for our answers because that foundation has been shown to be the most successful. We address ourselves to empirical, reliable events with multiple converging evidence, consistent with the scientific paradigm which have consensual validation and operationally / functionally defined elements rather than imaginary things. Those characteristics assure us that our knowledge is in the natural world or is reality and is the best knowledge available. This issue was extensively discussed in Chapter 1.

D. The Vehicle of Knowledge

From a perceptual perspective, all there is in nature is change. We react to changes in nature. If we see this page it is because the light changes as we move our eyes from the desk to the book. There are many types of change and many issues to consider when thinking about change. In this chapter, we are focused on predicting one change with another change. The death rate from infection changes as the result of a change in the amount of penicillin in the blood. Alternatively, the rate of a behavior changes as the result of the change in the consequences following that behavior.

II. Conceptual Precursor: Dynamics and Equilibrium

How are we to extract order from change? If knowledge is understanding how one thing changes as a function of changes in something else, or how to best predict changes in one thing based on changes in something else, then it should be apparent that our first task is to understand change. Change can be seen from two perspectives much like focusing on a flashing light in terms of periods of illumination or as periods of darkness. When focusing on how a measure changes, it is labeled the dynamics of the measure. **Dynamics refers to how behavior changes.** When focusing on how a measure stays the same, it is labeled the equilibrium of the measure. **Equilibrium refers to how behavior stays the same.**

A. Dynamics

Dynamics refers to the change in a system. In behavior analysis, dynamics refers to a change in behavior as the result of changes in some causal factor. Therefore, as a minimum, we must have a productive conceptualization of behavior change and its cause.

1. Conceptual Precursor: Determinants of Behavioral Variability

Science and behavior analysis presume absolute total determinism (i.e., all things have an empirical identifiable cause). Other views are possible.

a. The Assumption of Intrinsic Variability (no cause)

From this perspective, variability has no cause. It just happens and it, in principle, cannot be understood. This approach is anathema to science. Examples would be something such as "Johnny sometimes steals and sometimes is honest because after all he has free will", or "a pigeon pecks a key or not and there is no rhyme or reason to it."

i. Outside Organism

The unknowable and unpredictable change can be something unknowable and unpredictable about the environment. This view asserts that the natural world cannot be understood because sometimes things happen for no reason or an inexplicable reason (Figure 5.2).

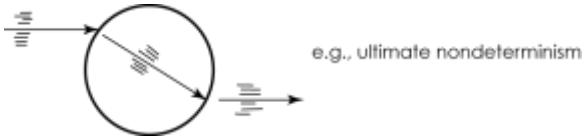


Figure 5.2 A representation of variability in an organism's behavior (the fluttery lines surrounding the output of the organism). In this case, an external cause that in principle cannot be accounted for or understood is the cause of the organism's behavior. That variability propagates through the organism.

ii. Inside Organism

The unknowable and unpredictable change can be something unknowable and unpredictable that happens inside of the organism. Free will is the label for a person doing something for a reason that cannot, in principle, be predicted by any means whatsoever (Figure 5.3).

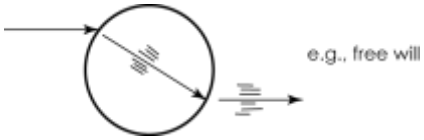


Figure 5.3 A representation of variability in an organism's behavior (the fluttery lines surrounding the output of the organism). In this case, unaccountable variance is added by the internal processes mediating behavior with the result of unaccountable variation in the output of the organism that, in principle, cannot be understood.

Clearly, an acceptance of either type of intrinsic variability would make any gain in the understanding of nature impossible. It would be impossible to make any inference based on experiments because the behavior could have been a random result (e.g., free will).

b. The Assumption of Strict Determinism or Extrinsic Variability (due to cause)

From this perspective, all variability necessarily has a cause. Note that a strict deterministic position is consistent with stochastic behavior that has no apparent determinant (chaos), if it is presumed that the determinant has not yet been identified. This is similar to an encrypted message. It appears random but with the encryption key, it is an easily understood message.

i. Outside Organism

This is the behavior analytic approach and is labeled externalistic in this text. Note that variability added within an organism that was itself the result of some previous environmental cause is still considered externalism. For example, it is often said that how a person reacts to an event depends on their personality. If the personality is seen as nothing more than the sum of prior environmental interactions, then the variability in their reaction as modified by their personality is still a function of their experience.

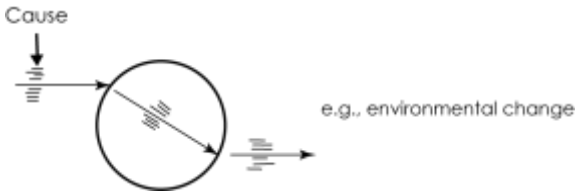


Figure 5.4 A representation of accountable external causation for the variability in an organism's behavior (the fluttery lines surrounding the output of the organism). In this case the cause of the variability in the behavior of the organism is in the external environment and could be determined.

ii. Inside Organism

This is a biological (if empirical) or cognitive (if non-empirical) reductionism approach and is labeled an internalistic approach in this text. Behavior Analysis as a matter of principle cancels out any internal process by dealing directly with the cause of the putative internal cause. Recall that if C is caused by B and B is caused by A, then A causes C. The internal process is irrelevant because it reduces to the environmental process causing the behavior.

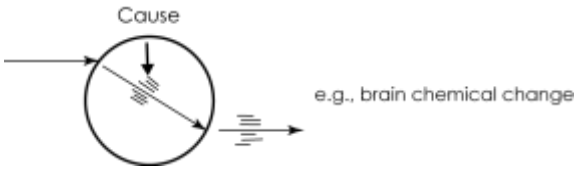


Figure 5.5 A representation of accountable internal causation for the variability in an organism's behavior (the fluttery lines surrounding the output of the organism). In this case the cause of the variability in the behavior of the organism is inside the organism and could be determined.

2. Three Types of Behavior Change or Behavioral Dynamics

a. Simple Dynamics

The first type of behavior change is simple dynamics. Simple dynamics are the change in behavior that result from a change in the independent variable. It can be one-directional or bidirectional (a change and subsequent return to the original state). Additionally, the change can be graded (levels of dependent variable related to levels of independent variable) or dichotomous with only two states to the dependent variable regardless of the magnitude of the change in the independent variable.

The gray arrows in the following figures draw attention to the change in the behavior, or when the y-axis value of the dependent variable changes. The x-axis position of the response to the IV change can be virtually anywhere along the x-axis following the IV. Only one possible position is illustrated in the figures below.

i. Bitonic Simple Dynamics

This class of simple dynamics is unstable in the changed state and the behavior returns to the original state regardless of the state of the independent variable (Figure 5.6). It is a temporary change following some change in the independent variable. An example would be someone looking up when someone entered a room. The person looks back down regardless of whether the new person stays in the room or leaves. It is a change and return.

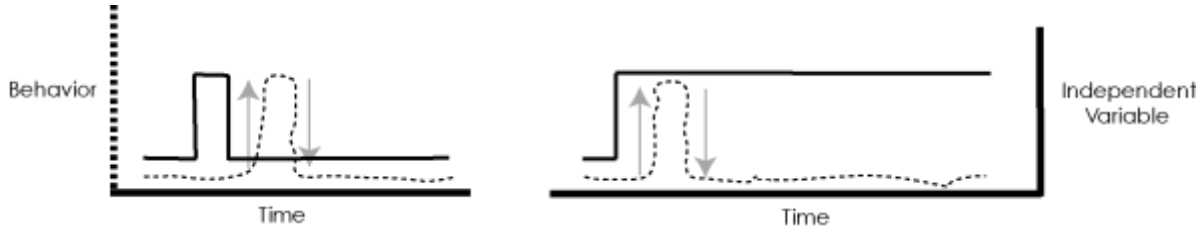


Figure 5.6 Bitonic simple dynamics. In the left frame, a momentary change in the independent variable the solid square wave causes a temporary change in the dependent variable the rise and fall of the dotted line. The left frame shows a change in the independent variable causing a temporary change in the dependent variable. The right frame shows a permanent change in the independent variable causing a temporary change in the dependent variable.

ii. Monotonic Simple Dynamics

This class of simple dynamics is stable in the changed state (Figure 5.7). An example of this type of change would be the amount of flame on a piece of paper after you apply a match. The paper continues to burn regardless of whether the match is removed or left under the paper. It is a change in behavior and no return.

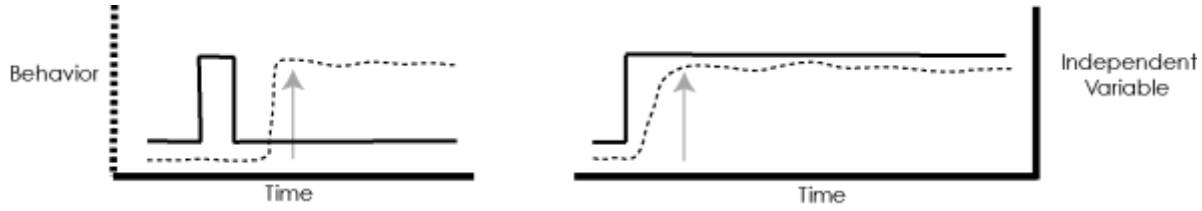


Figure 5.7 Monotonic simple dynamics. In the left frame, a momentary change in the independent variable causes a permanent change in the dependent variable. The right frame shows a permanent change in the dependent variable caused by a permanent change in the independent variable.

Complex forms of a monotonic dynamic could exist. A complex form of monotonic dynamics is illustrated by a bouncing ball (Figure 5.8). If a rubber ball is dropped onto a floor, it bounces in ever decreasing bounds until it comes to rest on the floor. The same thing happens with a pendulum, swinging in decreasing arcs until it comes to rest. In the larger view, there is a stable monotonic dynamic represented by the change in the ball from being aloft to resting on the floor. This change takes place in the form of a series of unstable bitonic dynamics whose amplitude diminish to zero across time (damped). It is a change with no long time scale return but a series of temporary returns.

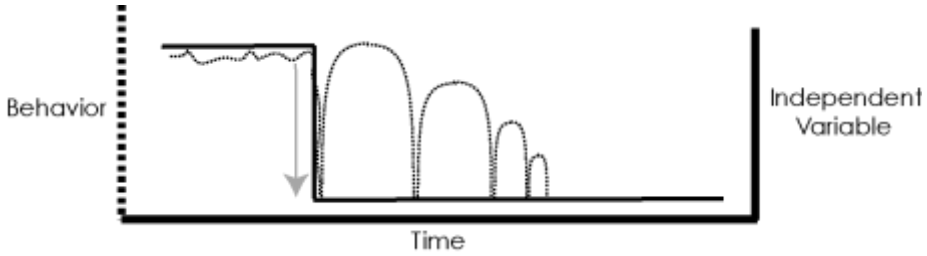


Figure 5.8 The left portion of the image depicts that Initially the dependent variable is in equilibrium with the independent variable. When the independent variable changes, the dependent variable changes in a series of unstable bitonic dynamics whose amplitude diminishes to zero across time. At that final point the dependent variable is in equilibrium with the independent variable again.

iii. Entrained Simple Dynamics

This class of simple dynamics is a change in the dependent variable that is entrained by the independent variable (Figure 5.9). That is to say that the state of the dependent variable is determined by the value of the independent variable, or that the dependent variable tracks changes in the independent variable.

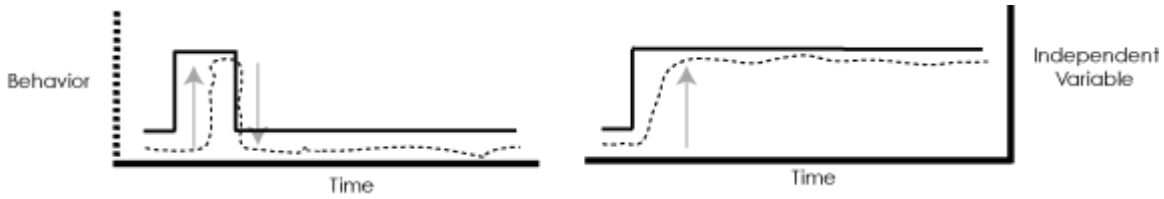


Figure 5.9 The left frame shows that the dependent variable changes with the temporary change in the independent variable. The right frame shows that the dependent variable changes and remains changed when the independent variable permanently changes.

Many cause-effect relationships in nature can be characterized as an entrained simple dynamic. Chapter 4 provided a coherent structure with which all of existence could be conceptualized as entrained simple dynamics with different time scales and therefore could be better understood. It was based on representing unit of analysis and time scale of adaptation in a common entrained bitonic dynamic format with only the axis labels changed. The IV, the DV, and the time scale were specific to each case.

The adaptation studied in behavior analysis is the semi permanent adaptation or behavioral equilibrium to a context or schedule of reinforcement. It is illustrated in Figure 5.10. That figure shows an onset and offset of an IV and a change with hysteresis in the seconds to days time scale in the DV.

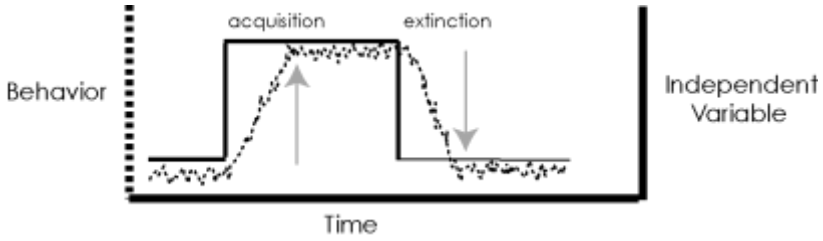


Figure 5.10 The left portion of the image depicts the dependent variable in rough equilibrium with the independent variable during baseline. After the change in the independent variable in the middle portion of the image, the dependent variable comes into rough equilibrium with the new state of the independent variable. When the independent variable returns to its original state in the right portion of the image, the dependent variable follows. Eventually the dependent variable comes back into equilibrium with the independent variable.

Simple dynamics does not refer to the value on the *y*-axis but rather refers to the change in the *y*-axis value effected by the occurrence of the independent variable. In each case of simple dynamics, the behavior change of interest is with respect to some one-time only nonrecurring explicit change in the environment.

The terminology and graphical representation used in Figures 5.6, 5.7, 5.8, and 5.9 can be used for individual punctate stimuli and individual responses or classes of events. As a result any could be used to illustrate events within any unit of analysis or time scale.

b. Synchronous Dynamics or Average Dynamics

The second type of behavior dynamics is synchronous dynamics. Average or synchronous dynamics are the commonalities in behavior to consecutive portions of a repeating independent variable For example, if someone worked all week to produce a product each Friday, their average accomplishment on each day of the week could be documented with a synchronous average with each day a different bin which would be the average of Monday's work then the average of Tuesday's work, etc.

Synchronous dynamics are not raw data but rather they are derived. They can be across any dynamic as long as it makes sense to average Bin 1 with Bin 1 and 2 with 2, etc. In each case, the averages provide what is common about portions of a repetitive behavior dynamic (for example, each day of the week).

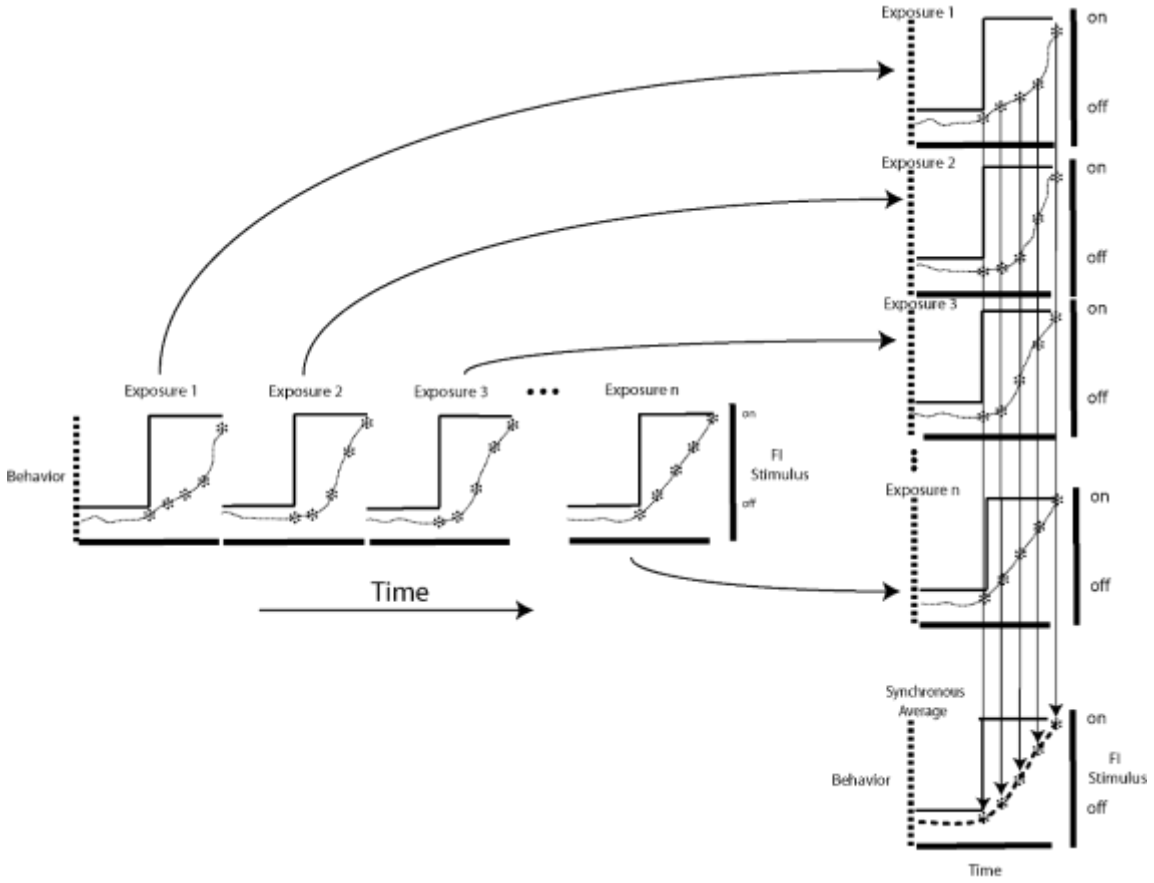


Figure 5.11 In this example, the behavior in n individual fixed-interval trials or exposures (four are shown) is averaged across each of five bins synchronized to specific portions within each trial. This results in a synchronous average for each portion of the FI for those n trials. This averaging process and the resulting synchronous average is depicted on the right edge of the figure

.

If the researcher is interested in what is common about the animal's reaction to each portion of a fixed interval schedule across many trials, then the average in each consecutive bin can be found. Figure 5.11 illustrates synchronous dynamics in a fixed-interval (FI) schedule. Behavior can be averaged across repeated

instances of each specific ordinal bin if the successive bins are synchronized to the event that controls behavior, in this case, the passage of time since the beginning of the interval. The first bin of the first trial is averaged with the first bin of the second trial and the first bin of the third trial etc. The second bin of the first trial is averaged with the second bins of the second trial and the third trial and so on. In this case, data from trial 1 or trial *n* can be freely interchanged, but the position within each trial with respect to the synchronization point is not free to vary. It is important to note that a synchronous average of an increasing likelihood of terminating an initial pause and a constant subsequent rate of responding would exhibit a smooth scallop pattern of responding across the fixed interval. The synchronous average behavior across an FI schedule is labeled an FI scallop.

c. Asynchronous Dynamics

The third type of behavior dynamics is asynchronous dynamics. These are the apparently random changes in behavior even after any trend in the measure of the behavior is gone. It is the variability that cannot be attributed to known specific changes in the environment. Most often asynchronous variability is very small, is unsystematic, and is accepted as too small to care about. It is often labeled random background noise, without actually suggesting that some things have no cause. Figure 5.12 illustrates asynchronous dynamics around an unchanging mean value in the upper right portion of the figure and around a trending mean in the lower right portion of the figure.

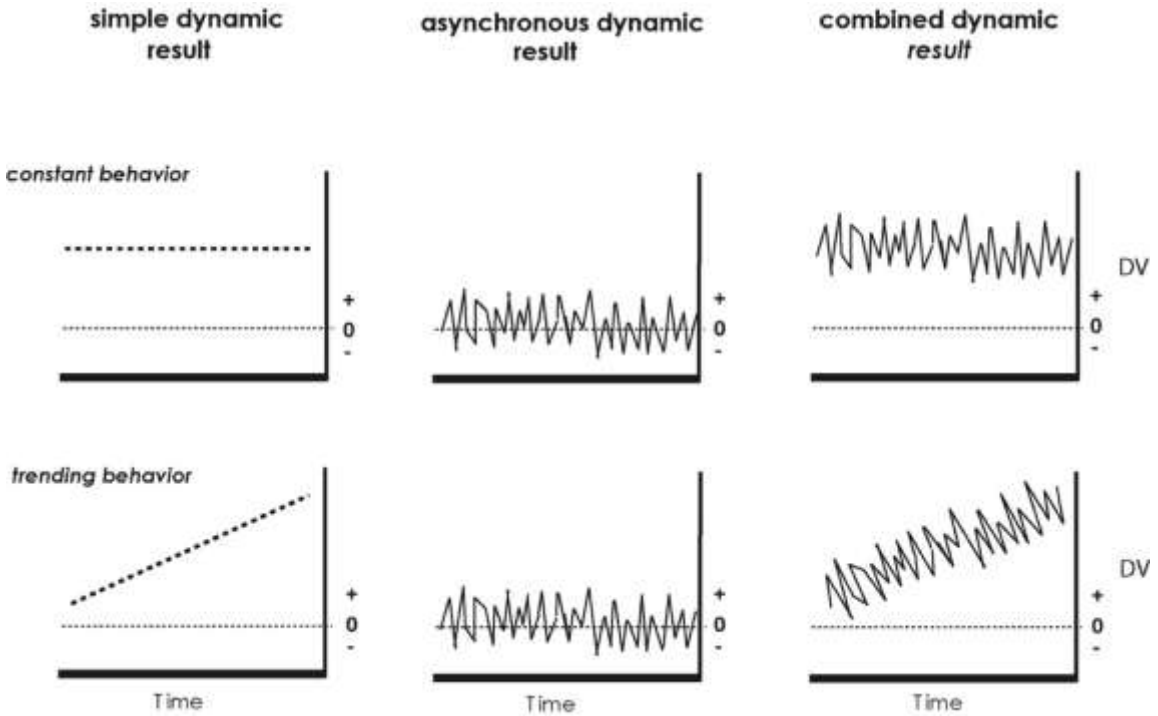


Figure 5.12 The left column depicts the basic simple dynamic result of the procedure. The middle column depicts the asynchronous variation around a value of zero. The right column depicts the simple dynamic combined with the asynchronous dynamic.

The behavior of living things typically exhibits some degree of chronic

asynchronous variability. This is problematic in that it is not associated with an obvious or understood change in conditions, it is not temporary, and has no apparent cause. An undamped system such as Brownian motion or background radiation continues to oscillate forever rather than to eventually cease (as would have happened with a bouncing ball). These dynamics can be quite large even under extremely regular conditions that have been in effect for very long time. It is typically apparently random and the mean of the variation is typically taken as zero. In research on asynchronous dynamics, the ordinal position of each instance is important and no item can be interchanged with any other item.

The right portion of the upper row of Figure 5.13 below illustrates an experimental treatment with a heavy line. The dependent variable is illustrated with a dotted line. The figure shows the dependent variable at equilibrium before and after the treatment with asynchronous dynamics at each stage. The treatment effect, a monotonic simple dynamic and the asynchronous dynamics have been partitioned and are illustrated to the right of the combined figure. Stable asynchronous dynamics are generally ignored and the mean and standard deviation of the variability is specified following exposure sufficient to eliminate any apparent consistent trends.

Figure 5.13 is also used to illustrate the impact of the ratio of treatment effect to asynchronous dynamics. The three rows of Figure 5.13 illustrates the same simple dynamic (e.g., experimental effect) with three different levels of asynchronous dynamics. The strength of an experimental effect is determined by comparison to the the asynchronous variance (the signal to noise ratio.) A putative experimental effect that is only marginally larger than the asynchronous dynamic cannot be accepted as a true effect without some other proof. It is for this reason that control of extraneous factors in an experiment are so important.

It is important at this point to go back to Chapter 3 and review the logical foundation for claiming a true cause rather than chance occurred and step through the figures illustrating decision analysis. The entire field of statistics can be seen as the separation of simple dynamics from asynchronous dynamics.

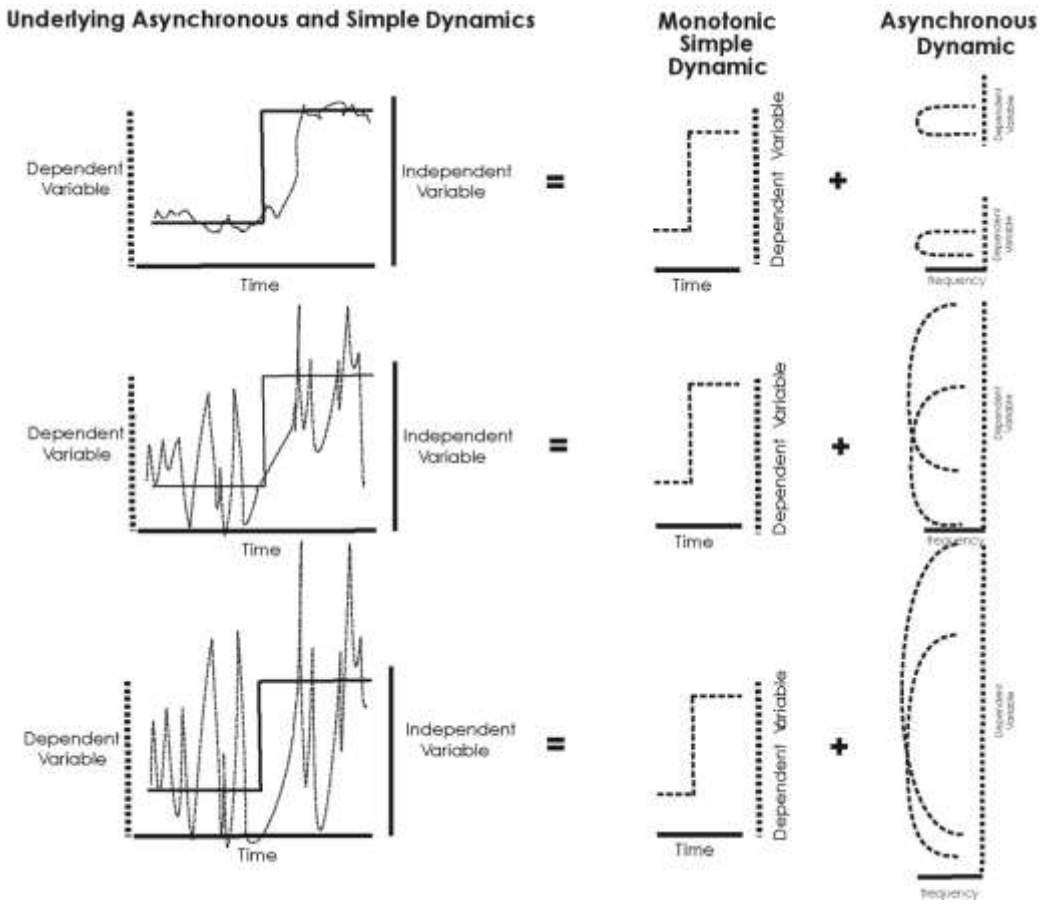


Figure 5.13 An illustration of a typical experimental manipulation and its behavioral effect. The left side of the left figure illustrates the behavior in rough equilibrium with the independent variable during baseline. Asynchronous dynamics in the behavior are apparent during the initial baseline. The independent variable changes as depicted in the right half of the left figure, after a lag the dependent variable changes, and asynchronous dynamics are again apparent in the new equilibrium. The behavior during this experiment be broken into two components. The next segment of the figure illustrates the treatment effect: a monotonic simple dynamic. The column in the right portion of the figure depicts two distributions that characterize the asynchronous dynamics: one in the baseline and one during the treatment.

B. Equilibrium

Understanding variability requires a productive conceptualization for how things equilibrate or stay the same as well as how they change. In behavior analysis, equilibrium refers to a steady state behavior or a behavior that shows no consistent trend. When a variable remains basically constant or constant around a mean value, it is said that the force causing an increase and the force causing a decrease are in equilibrium. Equilibrium refers to how behavior stays the same.

A mechanical metaphor for equilibrium is the resting state of a weight on the end of a spring (Figure 5.14). It can be unchanging or it can be fluctuating around a constant mean position. The spring pulls up and the weight pulls down. When the vertical position of the weight stabilizes at some point, the forces pulling in each direction are in balance.

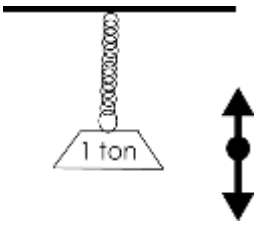


Figure 5.14 An illustration of mechanical equilibrium. The weight pulls down and the spring pulls up. The vertical position of the weight is the equilibrium point of the two competing forces.

Even if the weight is tapped, it oscillates around its equilibrium point and eventually settles back to its constant value. Adding or removing a weight in this weight-and-spring example is often used as a metaphor for the change in behavioral equilibrium caused by the change in a reinforcement contingency.

1. Three Types of Behavioral Stability or Behavioral Equilibrium

Dependent variables equilibriate to a change in the independent variable such as a new reinforcement contingencies. In the following figures the horizontal straight gray lines draw attention to the equilibrium or when the y-axis value of the dependent variable does not change.
The change in the dependent variable can be at any point along the x-axis after the IV changes. The following figures portray only one example. The stability of the equilibrium can be characterized with the following terms.

a. Neutral Equilibrium

The dependent measure is in equilibrium and virtually all changes are equally easy to effect, and after the change the behavior exhibits stability or equilibrium at that new value (Figure 5.15). This is the prototypical type of equilibrium. A typical example would be tapping a ball that had been resting on a plane with sufficient force to cause the ball to roll to a new location. The measure or value of the equilibrium state is permanently changed.

Figure 5.15 The figure shows the dependent variable in neutral equilibrium in the left portion of each frame. When the independent variable changes the dependent variable changes state and remains in that new state when the independent variables change is either temporary or permanent.

In the above example, the initial state of the dependent variable prior to the occurrence of the independent variable (that results in a monotonic simple dynamic) would be labeled a neutral equilibrium. Movement to any other state is

equally difficult and the new state is stable until another change in the independent variable changes the dependent variable to some other position. The behavior would then be in a new neutral equilibrium state. If, for instance, someone lives and works in a city, and then gets a job in some other city, they move to the new city, and they end up staying in the other city even when they lose their new job. The equilibrium at the start was neutral. The equilibration process did not have a "permanent" state, it did not bring them back to the original location.

In a typical operant research design which has several procedural changes (phases), the behavior is presumed to be changing form one neutral equilibrium to some new neutral equilibrium.

b. Stable Equilibrium

As is illustrated in figure 5.16, The behavior is in equilibrium and the effect of any given variable has only a temporary effect and the original condition is recovered (Figure 5.16). The initial state of the behavior prior to the independent variable that resulted in a simple dynamic would be labeled a stable equilibrium.

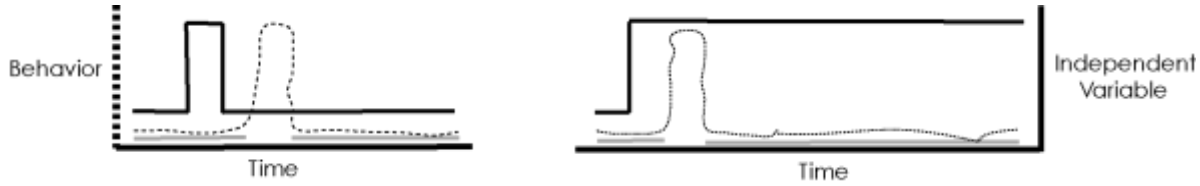


Figure 5.16 This figure shows the dependent measure in equilibrium with the independent variable in the left portion of each frame. When the independent variable changes, the dependent variable changes state but spontaneously returns to its initial state regardless of the state of the independent variable.

For example, in the studying example, the student goes back to studying after looking up regardless of the presence of the person. In the living and working example, the person moves back to the original city regardless of whether they lose their job or not. The equilibrium at the start could be considered a “natural state” with a return to that state regardless of the state of the independent variable. If this effect occurs in a typical operant research design, then the independent variable would be considered problematic. The effect would be labeled temporary, or the treatment labeled too weak, or the initial behavioral inertia was too strong. Any attribution would have to be proven.

c. Entrained Equilibrium

Entrained equilibrium is an equilibrium that is entirely dependent on the independent variable or simply tracks the independent variable (Figure 5.17). The behavior is stable with respect to the independent variable. It is "on" when the IV is in effect and it is "off" when the IV is off. This equilibrium is the measure referenced when the question is “what is the behavior caused by this contingency of reinforcement”.

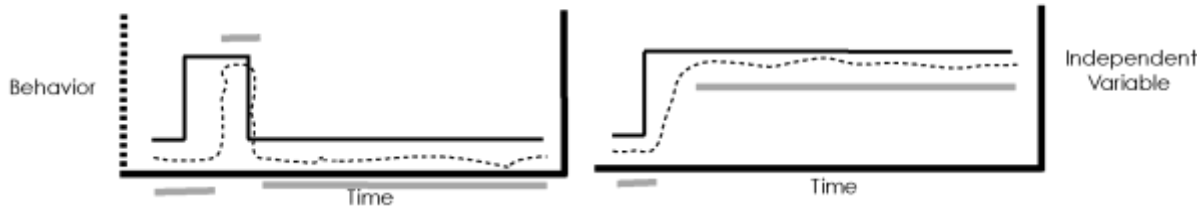


Figure 5.17 The figure shows entrained equilibrium in two situations in the left frame the equilibrium point changes with the independent variable. When the independent variable is not in effect the behavior is in one state when the independent variable changes the equilibrium changes and remains in that state as long as the independent variable remains in effect.

Figure 4.25 in the last chapter shows two different behavioral equilibrium states. One associated with the first schedule, and a different equilibrium associated with the second schedule. The differences in the equilibrium states is attributed to the difference in the schedules.

C. Conceptual Follow-Up: Dynamics and Equilibrium

Dynamics and equilibrium refer to two different aspects of a changing signal such as the behavior of an organism. Dynamics refers to how the behavior changes (the up and down gray arrows in the previous figures) while equilibrium refers to how the behavior stays the same (the horizontal gray lines in the previous figures). This issue is no more complex than looking at an elephant and noting the left legs, and then looking at the same elephant and noting the right legs. Just because the right and left legs are on the same elephant does not mean they are the same thing. Similarly, a flashing light has both periods of illumination and periods of darkness. The light periods are not the same as the dark periods.

III. Conceptual Precursor: Variance and Covariance

As a first step in understanding knowledge, we discussed how nature varies. For example, the lights in a room may be on or off, and a rat may be in the right or the left arm of a maze. Often, however, things are more complex. Dawn changes darkness into light in a continuous fashion. A person's weight goes up and down to a larger or smaller degree. Additionally, there are systematic relationships or covariance in nature; we flip the light switch and the lights go on; we place food in one goal box and the rat goes there. Not only that, there are continuous degrees of relationships in nature. When we speed in one town, we may rarely get a ticket while speeding in another town may almost always result in a ticket. All

covariance is not as perfect as a light switch and illumination level. As cigarette smoking increases, the incidence of cancer increases in a population, but everyone smoking does not get cancer, and many people get cancer that have never smoked. Some relationships are very strong and of one type, such as light switches and illumination level (often labeled "cause"), whereas others are weaker and are of another type, such as smoking and cancer (often labeled "covariance" as opposed to cause).

A. Variance

The dispersion in a variable is labeled variance; the more different the scores, the more variance. Formally stated, it is given as the sum of the squared deviations around the mean divided by the number of scores. It is therefore the average of the squared deviations. However, in typical usage the formal definition is not implied. It simply translates to "the variability". Suppose we go around a typical class and ask each person for their GPA (grade point average) and plot the data as follows (Figure 5.18).

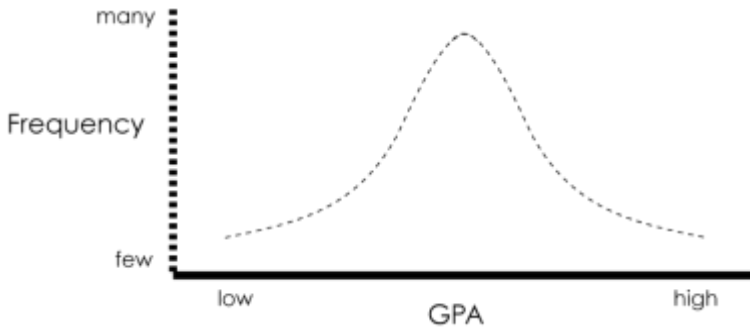


Figure 5.18 The distribution of grade point averages in a typical class. GPA is on the x-axis and frequency of each GPA is on the y-axis.

We would see that people differ with respect to GPA. Additionally, we would notice that there are more people of average GPA than very high or very low. The variation in the scores of this dependent variable is labeled variance: for some students, the scores are one thing and for other students they are something else. The task of research is to find out why our dependent variable scores are what they are, what causes them to be different, or at least to be able to predict them.

When we are in ignorance, our best prediction of a variable is to guess the mean. We would then be at the single point that is as close as possible to as many scores as possible in the data, but we want to do better.

B. Covariance

1. Covariance with Dichotomous Predictor and Dichotomous Predicted

Variation in a measure is labeled variance; when two measures vary together in some way, it is labeled covariance. A very simple mechanical example of covariance is a dichotomous change caused by a necessary and sufficient dichotomous precursor such as a light switch position (up or down) and the amount of light in a room (bright or dark). In the simple dichotomous case, the relationship is a special case of correlation and is labeled a contingency (Figure 5.19).

In terms of the box of weights suspended on a spring metaphor, which was presented earlier, the suspended box is first in the lower position. The weights are removed from the box and the suspended box rises, then the weights are returned to the box and the suspended box returns to the lower position.

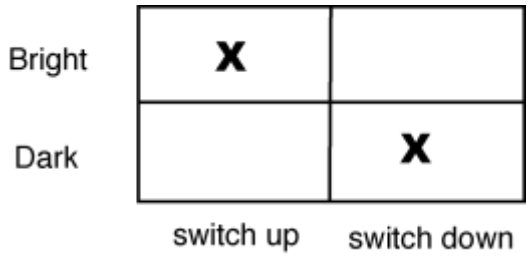


Figure 5.19 A simple example of a dichotomous relationship. Bright and dark go with switch up and switch down.

2. Covariance with Continuous Predictor and Continuous Predicted

Changes are often more complex than the simple dichotomous changes with dichotomous causal factors, just illustrated. Changes can be continuous with each increment in one variable like dawn rather than dichotomous like a room illumination. In the case of dawn, every possible intensity from darkest to brightest occurs, but they are correlated with the time.

Figure 5.20 The amount of money in a bank account as a function of the number of deposits of one dollar. The number of deposits is on the x-axis and the amount of money in the account is on the y-axis.

As a continuous independent variable completely controlling a continuous

dependent variable, we could also consider the amount of money in a bank account as a function of how many times a deposit of $1 was made (Figure 5.20). Note that the amount in the account could be predicted perfectly by knowing the number of deposits. Note also that in the absence of knowing how many deposits were made, guessing the mean amount in the account results in the least discrepancy between the guess and the actual amount when trying to predict the balance after any number of deposits.

Figure 5.20's scatter plot format provides for:

a. Continuous Predictor (X)

Number of deposits from zero to infinity.

b. Continuous Predicted (Y)

Amount of money in the bank account from zero to infinity.

c. Illustration: Covariance with Continuous Degrees and Types of Relationships Between X and Y

Not only can we have a perfect relationship between a continuous x and continuous y dimensions such as the number of $1 deposits and the amount of savings, but we can also have weak or strong relationships and even positive or negative relationships. These various relationships are most easily depicted as scatter plots where each dot is an individual and the x dimension is a predictor such as the amount of studying and the y-axis is the predicted such as the grade point average. The left frame of Figure 5.21 illustrates a weak relationship between the two variable while the right frame illustrates a strong relationship between the two variables.

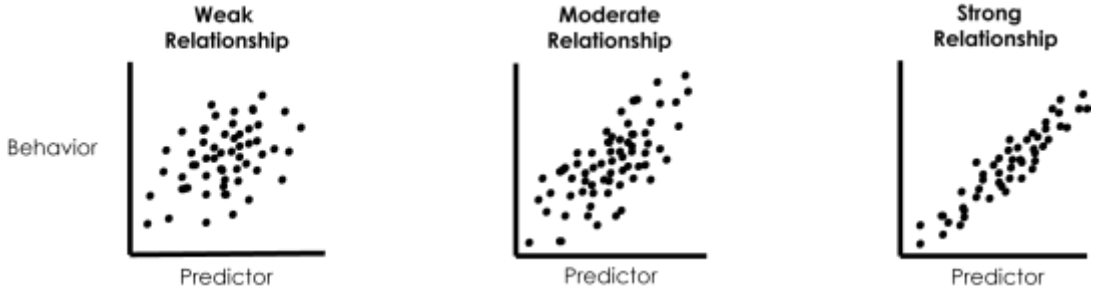


Figure 5.21 The left frame illustrates a weak relationship between predictor and predicted. The center frame illustrates a moderate relationship while the right frame illustrates a strong relationship between the predictor and the predicted. The strength of the relationship is indicated by the narrowness of the spread around a function which in this case is a straight line from the origin (but which could have any angle, intercept, and curvature).

Degrees of relationship can also vary from a positive relationship where more studying goes with higher grades, to no relationship where there is no relationship between studying and grades, to the right frame which illustrates a course where the more people study, the worse their grades (Figure 5.22).

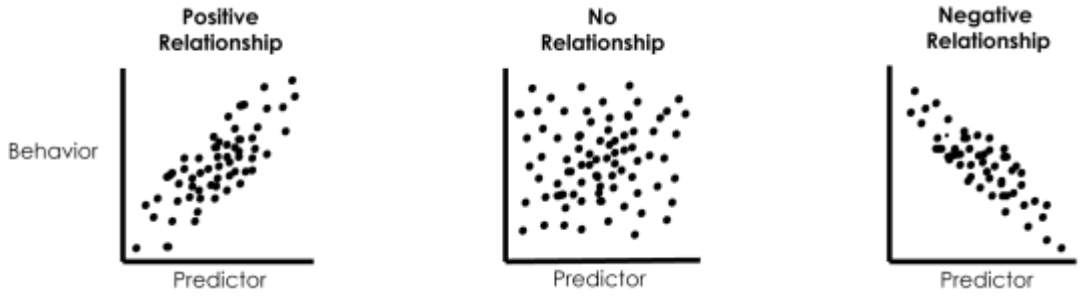


Figure 5.22 The left frame illustrates a positive relationship. The middle frame illustrates no relationship, while the right frame illustrates a negative relationship. The direction of the relationship is indicated by whether the function best representing the data points rises or falls as its position on the x-axis increases.

3. Multivariate Covariance

Multivariate change is when the change in a behavior is a function of more than one variable at a time. If a dependent variable is a function of more than one independent variable, it only makes sense to look at the dependent variable as a function of all the independent variables. Clearly a single dependent variable such as grade earned in a course, can change as the result of more than one independent variable such as both IQ and amount of studying. How the dependent variable changes as a result of the multiple variables may be crucial to understanding what's going on (Figure 5.23). In this light, the previous examples can be seen as special cases of what changes we could expect in the natural world. In those examples, we had only one predictor variable and one predicted variable; the single variable approach is labeled univariate research. In multivariate research, either the predictor or predicted can be measured in multiple levels. A subsequent section provides an example of multivariate covariance.

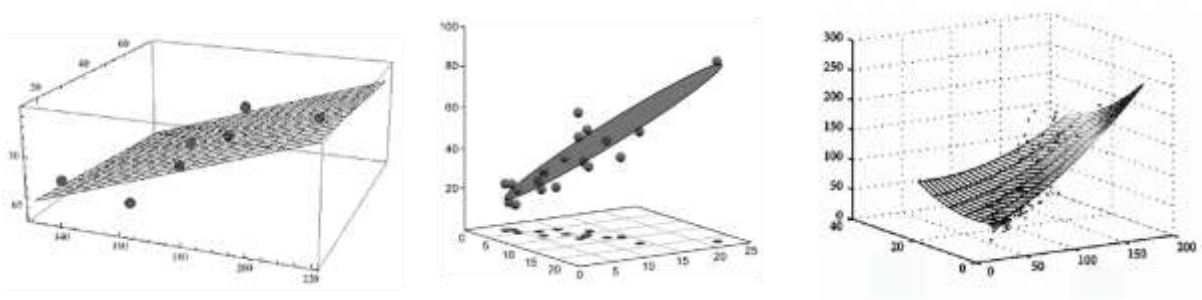


Figure 5.23 Three illustrations of multivariate covariance. The left frame is linear, the middle frame is a single vector in three planes, and the right frame is a curvilinear function.

a. **Number of Predictor Variables**
   i. **One (Univariate)**
   ii. **More Than One (Multivariate)**

b. **Number of Predicted Variables**
   i. **One (Univariate)**
   ii. **More Than One (Multivariate)**

IV. Knowledge is Behavior Controlled by Covariance

Knowledge is behavior controlled by covariance. Covariance is a relationship in nature that allows predictions that are better than chance. When we have knowledge about grade point average (GPA) such as the fact that people who study more get higher GPAs and people who study less get lower GPAs, then we can make a better guess about their GPA than to simply guess the mean of all GPAs. Based on the amount of time they study, we can guess lower GPAs for those who study less and we can guess higher GPAs for those who study more. We will be able to reduce error.

A. Conceptual Precursor: Covariance as Accountable Variance

Suppose we go around the class and ask each student for both their GPA and shoe size and plot them in the left scatter plot below (Figure 5.24). We go across the *x*-axis their shoe size then up the *y*-axis their GPA. We place a dot in that spot to represent that a person with that GPA and that shoe size occurred.

Next we repeat the whole plotting process by asking each person for their grade point average and hours studying and form the right frame in the figure below.

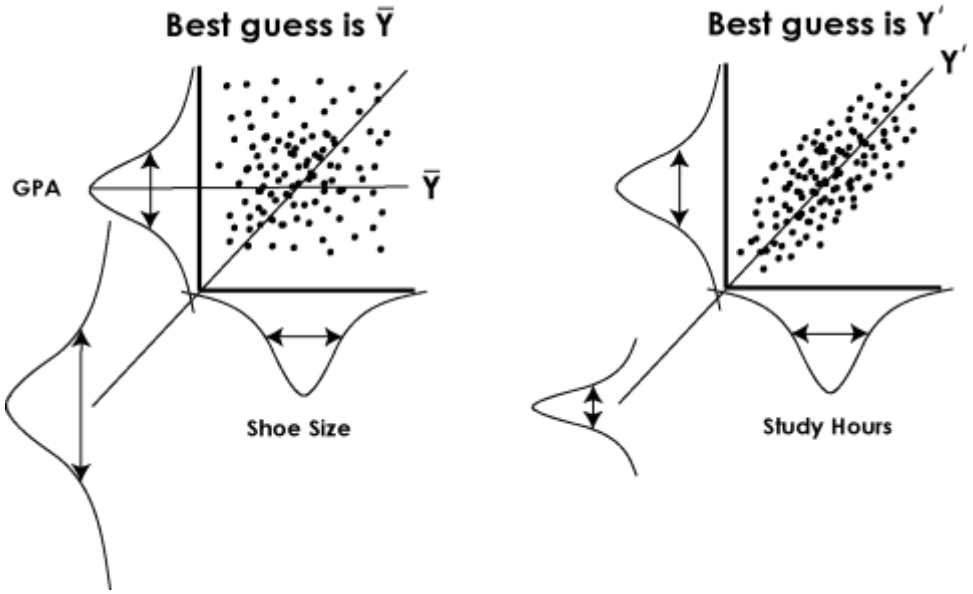


Figure 5.24 The left and right frames show scatter plots (with stylized values and relationships). The left frame shows no relationship while the right frame shows a moderately high relationship. Both frames have the same distributions on the x and y-axes. The frequency of each value along the x-axis is depicted below the x-axis. The frequency of each value along the y-axis is depicted to the left of the y-axis. The variability around the regression line (and the simulated regression line in the left frame) is depicted in the lower left corner of each frame. As can be seen, data points in the left frame could be further away from the predictor than they are from the mean of the y scores. Compare the width of the distribution to the left of the y-axis with the distribution around the diagonal that matches the predictor in the right frame. In the right frame, the data points are not as far from the predictor as they are from the mean of the y scores.

Note that the variability around the average Y (GPA) is the same in both figures (as it should be because it is the same measure), and the variability around the average X is the same in both figures as it was forced to be for this example. However, in the right figure, there is a relationship between the data in the two axes. We could find a way of looking at the figure (in this case up the line drawn at an angle through the origin) that dramatically reduces the error or variance around a central tendency. This is illustrated by the distribution drawn in the lower left corner of the right figure. If we had tilted the right figure at a 45-degree angle and the data point dots acted like marbles, then the stacks of marbles would have created the distribution in the lower left corner of this frame and would have been very close together. This variability or error is very much smaller than that on the *y*-axis of this right frame. This graphical difference is an illustration that there is not as much variability around *y* prime (y') as there is around the mean y or *y* bar($\overline{y}$). The two data sets have shared variance or are correlated.

The figure on the left has the same spread around the *x*- and *y*-axes, as the right figure but it does not have any "line" around which the spread is minimized more than it is by the mean *y*. A line from the origin similar to the one in the right figure is drawn for reference, but clearly the spread around it is worse than around the mean *y*. Note that the distance from the diagonal line to the top dot on the left side of the left frame and from the diagonal line to the bottom dot on the right side

of the left frame is actually longer than from the mean line to the top or bottom dot. In fact, any line of any angle or offset would fail to be better than the mean (i.e., the line that is parallel to the *x*-axis in the figure).

Prediction is relatively good in the right figure and poor (in fact zero) in the left figure. For instance, if you start on the *x*-axis with a shoe size (left figure) or hours studying (right figure) that you know, you can then look to see what *y* values have occurred for your given *x* value, you can predict what GPA will occur in each case based on that information. If we know a person's shoe size (left figure), we cannot accurately predict their GPA very well (nothing is better than the mean or $\overline{y}$) whereas if we know their hours studying (right frame), we could predict their GPA with reasonable certainty (we could predict with y′). As can be seen on the left, reasonable predictions are not possible with a zero relationship; no information is available at all, whereas with the strong relationship on the right, accurate predictions can be made.

The "correlation coefficient" and the "percent variance accounted for" can be seen as an index of how much smaller the variance around the predictor (y′) is as compared to the variance around the mean y.

The two relationships depicted in Figure 5.25 as scatterplots can be illustrated in yet another way to emphasize percent variance accounted for. Each circle below (Figure 5.25) represents the variability in a set of numbers. The area of the circles labeled Y represents the variability on the *y*-axis (the variability in the GPA). The area of the circles labeled X represents the variability on the *x*-axis (shoe size and study hours). Note that all four circles are the same size reflecting that the variability on both *x*-axes and both *y*-axes are all the same.

The intersection of the two circles in each pair of circles in Figure 5.6 represents the covariance in that relationship. The area in circle Y remaining in addition to the overlap represents the residual variability around the best-fit line through the data points or the variability in Y not “explained” or accounted for by the variability in X. The unexplained variance is the variability in the distribution around the best predictor. The best predictor is the mean in the left scatter plot and the regression line (the diagonal line from the origin) in the right scatter plot. The explained or “accounted for” variance is the difference between the distribution on the *y*-axis and that around the best predictor.

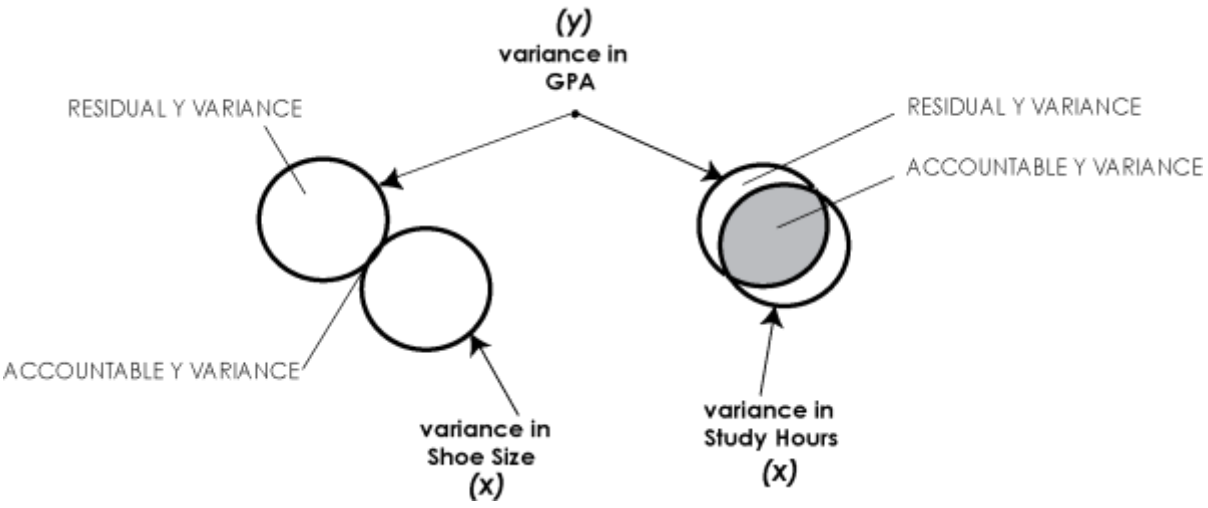


Figure 5.25 The variance across the x and across the y-axis in each frame of Figure 5.24 is illustrated as a circle. Note all four circles are the same size. This figure has Venn diagrams illustrating variance accounted for as the intersection of the data on the x- and y-axes. In the left pair, there is no overlap or no variance accounted for, while the right pair shows substantial overlap and substantial variance accounted for.

B. Example of Understanding Behavior Change by Understanding Multiple Sources of Variance

Research accounts for or explains variability by demonstrating less variance with the partitions provided by the "cause" or "predictor" and more variance without the cause or predictor. The answer to the question of why students get different grades is discovering the way the scores could be grouped (such as by amount studied). Most of the variability would then be understood to be related to hours of studying. Variance is said to be accountable to the degree we can specify a covariate and by how much the variance in the scores is reduced. It is said to be residual when we cannot specify a covariate or understand why.

As a more complex (and realistic) example, we could consider a multivariate example. Imagine that many researchers had collected data for several years on the average amount of time spent reading research papers and the average grade point average within psychology courses for many many students and found that there was no relationship between amount of time spent reading research papers and the grades in psychology. The figure below (Figure 5.26) was their data.

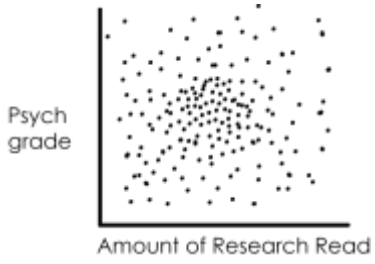


Figure 5.26 A scatter plot showing no relationship between the x- and y-axes. When the axes provide amount of research read and average psychology grade.

Suppose a behavior analytically inclined student realized that answering test questions with the empirically supported answer based on published research was detrimental in some psychology courses. Suppose that that student went back through the data collected by the original researchers and found an additional covariate that would reduce the variance in the psychology grades as a function of amount of research read. For example, by partitioning courses into "tough-minded," "medium," and "soft-minded," the student found the following (Figure 5.27):

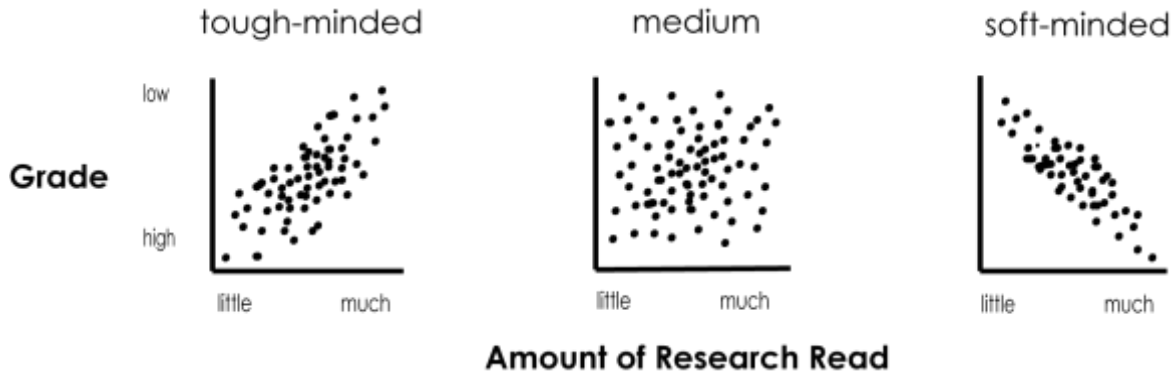


Figure 5.27 Scatter plots showing different degrees of relationships between studying and grades in tough-minded, moderate-minded, and soft-minded courses. There is a positive correlation between studying and grade in the left frame and a negative correlation in the right frame.

The student would have reduced the variance in the grades and would have discovered an important multivariate relationship.

In the following figure (Figure 5.28), the dotted line is a regression plane indicating how grade earned is a joint function of amount of research read and the paradigmatic orientation of the course. Across the front edge of the cube, the dotted line represents the relationship between hours of reading and grade earned in a course that covers material that has strong empirical support (the more the reading, the higher the grade). The dotted line across the back of the cube depicts the relationship between amount of reading and earned grade in a course based on non-empirical conjecture. In that course the more the students read about what actually happens in the natural world, the worse the grade they earn.

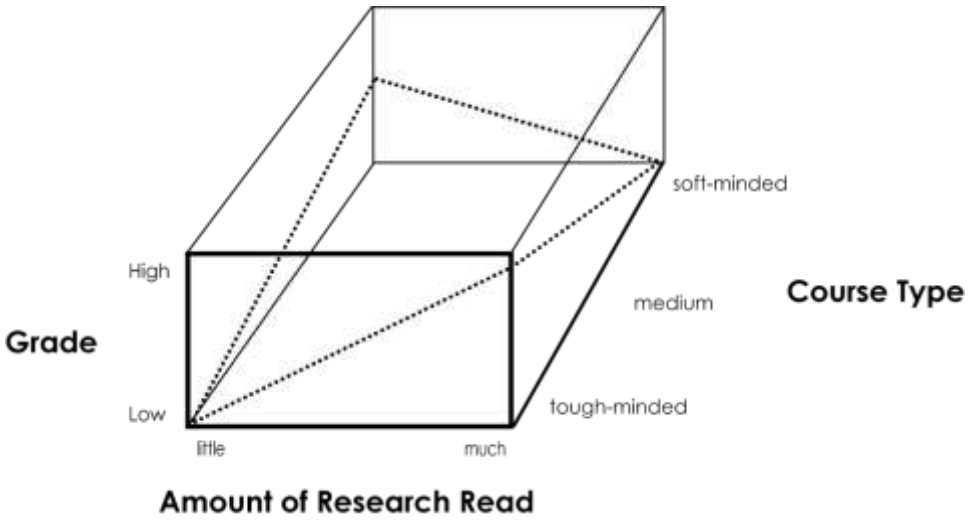


Figure 5.28 A multiple correlation represented in a three-dimensional space. Amount of research read is across the x-axis. Grade is represented up the vertical y-axis, while type of course is represented back along the z-axis. The three scatter plots in Figure 5.28 would be slices through the cube at the levels of tough-minded, medium, and soft-minded.

This general way of conceptualizing covariance is especially useful in complex circumstances such as where variations on some factor cancels out an effect. As the above example illustrates, if paradigmatic orientation were not specified, then it would appear that when the mean across all courses is considered, the amount of research read is not correlated with the grade earned. This would be true because for the "soft-minded" courses; there is an inverse relationship between studying and grades.

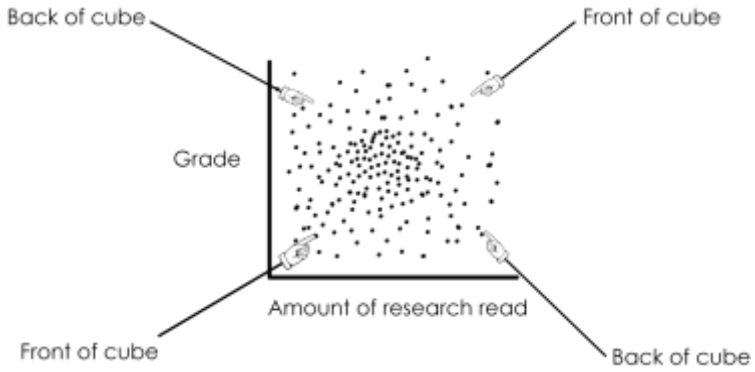


Figure 5.29 The scatter plot of grades as a function of amount of research read with labels pointing out where the dots are coming from on the z-axis of Figure 5.29. The removal of the z-axis information zeros out the correlation.

A person standing in the front of the cube (Figure 5.28) looking through to the back would see Figure 5.29. The dots seen in the upper left of Figure 5.29 would be coming from the back of the cube. The dots in the lower left would be coming from the front of the cube. The reverse would be true of the dots in the right of Figure 5.29.

1. Conceptual Aside

The individual researcher is obliged to attack the major sources of variance in the phenomena of interest first, and report stability and accountable variance of the same magnitude as, or better than, other researchers in the field. In a sense, status in science goes to the researchers who have the least variability remaining in their data after their explanation.

C. Interpretations of Accountable Variance

In the Venn diagram depiction of covariance in Figure 5.25, accountable variance is the overlap between the two circles. There are two basic interpretations of accountable variance. They differ with respect to what is known, or what information is specified, and the degree of control over the environment offered by that information.

1. Cause-Effect Interpretations

Note that it is necessary to have experimentally manipulated the relevant variables to prove that a cause-effect relationship exists. For example, flipping the light switch causes the illumination level to change, or that reinforcing behavior causes that behavior to increase in probability. Causation is treated more thoroughly in Chapter 7.

2. Description Only Interpretations

Sometimes we only know that things go together. We may not know which of the two events comes first. Social respectability and wealth covary. One can be predicted from the other but one does not force the other. Does social status make you wealthier or is being wealthy give you social status? Any of three relationships could underlie the prediction. It could be A causes B (A-->B); B causes A (B-->A); or C causes A and B (C-->A and B). Subsequent experimental research could find the order of the effect and the cause for the change but until the research manipulating variables is done, the relation is only a correlation. It is important to realize both 1) that knowing only that two things covary is a substantial and important piece of information. It allows prediction better than chance even if it does not allow the inference of causation, and 2) that without systematic experimentation causal relationships are not proven.

D. Potential Reaction Strategies to Residual Variance, Error, or Ignorance

When we identify a systematic relationship, we have removed the accountable variance (the overlap in the Venn diagrams). The next question is obviously what to do with the variability that's left over that we do not understand. This is the variability around the regression line that is illustrated with the distribution in the lower left corner of the two frames in Figure 5.24 above. When multiple

sources of variance are removed, the order of removal should follow in the order specified by the relevant theoretical view.

1. Experimental Solution

The obvious and productive solution to the problem of residual variability in the data from the subjects is to do an experiment that answers "why." Why do some individuals score higher and some lower in spite of how much they study? How can we predict which individual will score higher or lower in spite of how much they study? What will change an individual to a higher or lower score? What additional variable will account for additional variance. For example, a students GRE score or IQ may reduce the variance in GPA.

2. Withheld Judgment

In the absence of an experimental solution, the best choice is to withhold judgment. The withholding judgment position could be considered different than a "true score" position (detailed below) to the extent that it does not assume that the residual variance is random error, as a result the withheld judgment position is therefore more likely to eventually lead to an experimental solution.

3. Assumption of "True Score" and Random Error

This approach is based on what is labeled "true score theory." See Chapter 11 for additional information. It allows the researcher to pass over the problem of residual variability. A property of randomness is that deviations occur to either side of the actual "true" score to the same extent. The mean of those random errors therefore cancels that error because the mean of random numbers is zero. If we presume that our obtained scores contain a random error, then the mean will be the true score. If we have unaccounted for variability in our data, we can presume that it is random and of no interest by taking the average of our scores. However, we are: 1) presuming something (randomness in error) which we do not necessarily know to be true; 2) ignoring something which may be of importance; 3) giving up opportunities to explain variability; 4) assuming that each element in the group over which we are taking the mean is identical; and 5) assuming that the relationship between the elements is linear. Undoubtedly some variability should be passed over. However, it is equally true that some variability is of great consequence.

4. Delegation of the Problem of Residual Variance

Not every phenomenon has its causal factors within the interest of a given researcher.

a. Acceptable Delegation

When the causal factors are known to be in some other domain of molarity or time scale, they can justifiably be dismissed or passed on to someone else because they are not of interest.

b. Unacceptable Delegation

Unfortunately, all too often, unsophisticated researchers attempt to duck the problem of residual variance by automatically blaming it on something outside their responsibility or expertise. This is an unacceptable delegation when done in the absence of research that shows that the causal factors are actually in some other domain. To make matters worse, those researchers then often act as if they had answered the question rather than drawing a blank. Delegation only appears to give a dispensation for not solving the problem. Examples would be contending in the absence of evidence that there is a biological explanation for variance in psychological data or asserting that there is a developmental explanation for variance in learning data. In the absence of evidence, these deferrals are different from experimental solutions because the investigator who invokes them simple asserts that they are true and then acts as if the problem is understood by using the invoked other paradigm as an explanation rather than a description of a possibility. Passing an unsolved problem to some other domain is a mark of ignorance, not a badge of successful research.

5. Assumption of Nonlinear Dynamics (Chaos)

There are ways for a few simple completely deterministic variables to interact such that the result is a seemingly random series of measures (this is popularly known as “chaos theory”). The resulting variations cannot always be proven nonrandom by simply observing the output. An example would be a television signal or computer file that was encoded so well it appeared random to every test known.

Without some coherent and broadly based theoretical framework and substantial empirical support for a particular nonlinear dynamical causal factor, “chaos” is not an explanation. Rather, it is taken for grated given a commitment to strict determinism. Appealing to some unspecified nonlinear dynamics is nothing more than declaring that you don’t know what caused the effect but that you are sure it had a cause.

In principle, a researcher could develop a model of the processes underlying the dynamical behavior of the signal and prove that the signal was “chaotic” as opposed to being random.

V. Conceptual Follow-Up: The Task of Research is to Find and Understand Covariance

If knowledge is behavior under the control of covariance in nature, then the obvious task of research and practitioning is to find and understand covariance. This is the raison d'etre of a functional analysis. What changes in the environment go with, or cause the changes in the behavior of interest? Alternatively put, the obsession of behavior analysis for research is an obsession for acquiring knowledge, or an obsession for enabling the behavior of its practitioners to be controlled by the real world rather than superstition.

CHAPTER 6

Characteristics of Knowledge Gathering or Research

I. Conceptual Review: What is Knowledge?

II. Paradigmatic Context of the Research

A. Paradigmatic level of knowledge
   1. most global context (field)
      a. molarity of the field, level of analysis, or unit domain
      b. time scale of the field, time scale of adaptation, or time domain
   2. context (research specialty or area)
   3. local context (researcher's own lab)

B. Conceptual follow-up: value of integration into a paradigm
   1. re: validity
   2. re: generality/usefulness

III. Functional Adequacy of the Information Obtained by the Research

A. Structural information: Characteristics of the immediate-term reaction, or the capacity of the organism

B. Functional information: the functional relationships governing the emergence or governing the expression of a behavior
   1. immediate time scale adaptation
   2. short time scale adaptation
   3. medium time scale adaptation
   4. long time scale adaptation

IV. Rationale for the Research

A. For curiosity

B. Principled origin
   1. construction of functional context (theory building)
      a. relevant / irrelevant variables
      b. parameter documentation
      c. functional similarity
   2. evaluation of an explanation, theory, or model

V. Phase of the Research Helix

A. Analysis
   1. empirical analysis
   2. theoretical analysis

B. Synthesis
   1. empirical synthesis
      a. direct synthesis
      b. demonstration with other subjects, apparatus, or procedures
   2. the development of a paradigmatically consistent explanation or theory development
      a. prediction
      b. integration of divergent phenomena
      c. general theoretical model

VI. Domain of Applicability of the Research

A. Self-referential only
B. Predicting isolated treatment effect
C. Prediction across the entire range of the independent variable
D. Predicting across the widest possible class of independent variables with the fewest restrictions, or "laws"

VII. Conceptual Follow-Up: Threats to Meaningful Knowledge

CHAPTER 6

Characteristics of Knowledge Gathering or Research

The present chapter is the second chapter on knowledge. The first defined knowledge as behavior under the control of covariance in nature. This chapter presents miscellaneous characteristics, features, or aspects of knowledge to round out our understanding of one of the important products of science.

I. Conceptual Review: What is Knowledge?

Recall that the only definition of knowledge that is independent of opinion is completely externalistic. It is totally independent of any mentalistic or internal entity. It is nothing more than a covariance in nature, or more punctiliously stated, behavior under the control of a functional relationship in nature. Other views simply add inferences to this core. Activities that generate or gather information about covariance in nature, or knowledge, are labeled research.

II. Paradigmatic Context of the Research

All knowledge can be seen as the result of some type of knowledge gathering or research. The scientific paradigm, could be seen as a way of assuring its practitioners that the covariance is precisely what it is purported to be and that the conditions under which that same covariance can be expected in the future is specified as correctly as possible. Recall Section I in Chapter 5.

A. Paradigmatic Level of Knowledge

1. Most Global Context (field)

Once a researcher chooses to explain a phenomenon within a level of molarity and a time scale, other fields are rarely considered. An explanation is considered acceptable or complete if it is confined to the level of molarity and time scale within which the phenomenon is measured. Even though a totally complete explanation of something must include all levels of molarity across all time scales, that goal

would be seen as unnecessary and has not yet been fulfilled in the many lifetimes of every scientist that ever lived.

a. Molarity of the Field, Level of Analysis, or Unit Domain

For example, organismic adaptation or “psychology” (behavior analysis) rather than cellular adaptation ("biology").

b. Time Scale of the Field, Time Scale of Adaptation, or Time Domain

For example, short time scale adaptation or “learning" rather than "perception”

2. Context (research specialty or area)

In point of fact, a researcher rarely ventures beyond a specific context or research specialty that is a subset of their chosen unit and time scale domain. Examples of these more local contexts would be “matching” or “timing” within the field of learning.

3. Local Context (researcher's own lab)

An example would be scalar expectancy theory of timing or behavior theory of timing. Its important to note at this point that sometimes research is carried out with very little connection to the broader context of the research. This is perfectly acceptable, but it can also spell the doom of a lot of work. The work can be so idiosyncratic that virtually no one but the investigator or their students cares about or can benefit by the knowledge. When doing research, it may be a good exercise to consider how the research bears on a wide variety of research specialties within the field.

B. Conceptual Follow-Up: Value of Integration into a Paradigm

The degree to which knowledge is integrated within its paradigmatic context (in the previous example, science, psychology, and learning) determines two important aspects of the information, its likely validity and its usefulness.

1. Re: Validity

Validity refers to the degree to which the model matches what is labeled reality. Knowledge well integrated within its paradigmatic context has a wide variety of support and is therefore likely to be valid. In a sense, all phenomena within a paradigm provide multiple converging support because they are all consistent with the same principles, while knowledge poorly integrated into its paradigmatic context has only itself to provide proof or support. The discussion

section of a journal article is specifically tasked with making a coherent argument for this essential information.

2. Re: Generality/ Usefulness

Paradigmatic integration enables the obtained relationship to be more easily generalized and used more effectively because its relationship with other contexts and processes is well understood. Knowledge well integrated within its paradigm has many aspects that are "pre-understood." Its underlying machinery has generally already been thought through. For example, for a behavior analyst the enormous ramifications of the term reinforcement in a sentence is already well understood and the sentence thereby transmits more information. The information in the sentence can be applied to a vast array of situations that have a "pre-understood" relationship with each other.

III. Functional Adequacy of the Information Obtained by the Research

When studying behavior, two distinctly different classes of questions emerge. One type asks things such as, "How fast can a pigeon peck," or "How many colors can pigeons discriminate?" A second type, one that's vastly more important to psychology, asks things such as: "Why does this type of stimulus condition result in this type of behavior?" or "Why does this type of experienced relationship produce that type of rate change?" Note that neither of these classes of questions necessarily requires an internal explanation. Explanations that appeal to higher or lower levels of molarity are a different issue. The present issue (functional adequacy) has to do with whether a simple isolated property of behavior without a covariate or cause is specified, or a functional relationship between changes in the environment and changes in the behavior is specified.

A. Structural Information: Characteristics of the Immediate time scale Reaction or the Capacity of the Organism

This type of research is focused on determining the pattern in the behavior or the capacity of the organism under a single condition; for example, "what does the pigeon do?" It characterizes behavior without specifying what it is a function of, or how it came to be. No functional relationship is specified. Structural information could be characterized as answering the question "what."

Examples of this class of information would be the specification of how fast a pigeon can peck, or the sensory capacity of a cat, or the memory span of a person, or the pattern of walking used by various insects.

All of these structural questions are immediate time scale phenomena. They

are the reaction of an organism to something without the characterization of how changes in the behavior are a function of changes in the environment. None of these effects are exemplars of short time scale adaptation and are not a core element of behavior analysis.

B. Functional Information: The Functional Relationships Governing the Emergence or Governing the Expression of a Behavior

This is the specification of the functional relationships relating behavior to its controlling or causal factors, for example "how did the behavior come to be?" either in the sense of how a property of the behavior is a function of a property of a stimulus (its expression, or an immediate time scale effect) or what experience was necessary for the behavior to emerge (e.g., its emergence or origin such as in a learned reaction or an evolved instinct). Functional information could be characterized as answering the question "why."

This activity describes changes in behavior and how that behavior is a function of some causal factor. This type of research documents the environmental causal determinants of the behavior. The causal factors can be across any time scale factor. Time scale issues were more fully developed in Chapter 4, but to review:

1. Immediate time scale Adaptation

This class of information specifies how the expression of the behavior is a function of some property of a stimulus change.

2. Short time scale Adaptation

This class of information details the behavior changes as a function of the correlation of stimuli and behavior with subsequent outcomes (reinforcement contingencies, or schedules of reinforcement). It is the primary focus of EAB.

3. Medium time scale Adaptation

This class of information details the behavior changes as a function of the shared contingencies across multiple reinforcement contingencies.

4. Long time scale Adaptation

This class of information details the behavior changes as a function of the correlation of specific behavior with reproductive success or evolution.

IV. Rationale for the Research

A. For Curiosity

It may be that some research question that resulted in documenting some new functional relationship interested someone and that's a good enough reason. If it interests them, then that means some implicit theory they believed did not prepare them for the event that piqued their interest. The research was not guaranteed to be of wide interests, but it may be of significance to others too.

B. Principled Origin

Alternatively, the research or knowledge gathering may be systematically pursuing an explanation for a phenomenon; or the research may flow from some theoretical position and will clarify some specific theoretical question.

1. Construction of Functional Context (Theory Building)

This type of knowledge gathering systematically obtains facts as well as the necessary other information to develop a coherent frame of reference or context for meaningful explanation. The following enumeration illustrates the kinds of procedures or kinds of information that could be obtained.

a. Relevant / Irrelevant Variables

What are functionally significant variables and which are irrelevant or are simply adding noise?

b. Parameter Documentation

What specific changes in the dependent variable are caused by what specific changes in the independent variable? For example, as the magnitude of reinforcement increases, exactly how does the response rate change? How could the effect of the class of all values of the independent variable be characterized? For example, response rate is a hyperbolic function of the reinforcement rate.

c. Functional Similarity

What other well-understood functional relationships have properties that are similar to the effect of interest so that even more fundamental explanations common to both phenomena could be revealed?

2. Evaluation of an Explanation, Theory, or Model

Often we carry out research to evaluate an inference of a theory. We could deduce some experimental test such as: "according to my understanding of the

theory, if we double the reinforcement rate on Schedule A, then the rate of behavior should be halved on Schedule B."

Note that a single positive finding (i.e., one that is consistent with the predictions of the theory) supports the relevant portion of the theory but does not prove it. Many different processes could result in the same effect so some process other than the theory's process could be responsible for the obtained effect, That is to say the proposed process is sufficient for the effect but is not necessary.

If some unknown process is masking the effect of the experimental variable, then that unknown process must be discovered and integrated into the theory, without that addition the theory fails to predict correctly.

V. Phase of the Research Helix

Traditionally, research is partitioned into analysis or breaking things down into their component parts and synthesis or building something from the component parts to prove the conclusions based on the analysis is correct. As a general rule of thumb, these categories are easy to define. However, some specific research examples could be seen as having aspects of both analysis and synthesis.

A concrete example of analysis and subsequent synthesis would be a space alien taking Beethoven's 7th Symphony and breaking it down into its component instruments (piano, violins, etc.) and component notes then with that knowledge synthesizing Rhapsody in Blue or music of their own.

A. Analysis

This aspect of knowledge gathering proceeds by breaking a phenomenon down into simpler elements and collecting data. This most typically occurs with some experimental procedure tailored to accomplish specific goals. Analysis is based on the assumption that the action of a whole is the result of the action of its parts and their interaction. This approach argues that by isolating the parts and coming to understand their simple processes individually, then complex wholes can best and most efficiently come to be understood. The belief is that the complexity and unpredictability of wholes is due to the action of the many small difficult to control processes making up the whole.

1. Empirical Analysis

This class of analytical experiments analyzes a relatively complex behavioral phenomenon by breaking it down into each of its presumed component empirical processes and describing the empirical functional relationships pertaining to each component.

Analysis is specifically designed to obtain information concerning the nature of the underlying behavioral process by breaking the phenomenon into its parts.

This is the process of isolating active variables or ingredients, or the removal of irrelevant or confounding variables.

For example, if given boxes and a hanging banana, a chimpanzee will move the boxes to form a ladder and will get the banana. We can easily show that that activity is not some mystical or transcendental insight by using analysis. By providing or withholding various component antecedent experiences, we get predictable variations in the final behavior. Experience with each essential precursor is necessary for the complete behavior to emerge.

An extremely important realization for a researcher to make is that the task is to show why the behavior occurred as the result of simple environmental experiences by proper analysis. To show that the behavior had to be the result of an unfathomably complex animal - because the researcher was unable to isolate the cause- is to have failed as a researcher: The question "why" has not been answered. Thus, "... and then a miracle happens," or "... and then the animal realized the right solution," or "... and then the animal used its cognitive map" or "then the space aliens told the animal what to do" type of research answers are pointless. Rather than uncovering a cause for the behavior, the researcher needlessly demonstrated once again that sometimes animals do things that appear very "intelligent." We already know that. The point of research is to discover the actual "why" not to make up an unproven plausible excuse which only perpetuates the ignorance we started with.

The task of research is to discover the set of experiences and environmental conditions that inevitably lead to a behavior. In that case, the animal could be seen as a passive entity simply reacting to events in the environment because the behavior is inevitable given those environmental conditions. In that sense, the animal could be seen as "stupid." The task of a researcher is to detail the conditions that control an animal's behavior. To be inadequate to that task could be seen as the researcher being stupid. The demand for meaningful results of research has led to the pitiless dictum "stupid animals prove the researcher smart while smart animals prove the researcher stupid."

2. Theoretical Analysis

This class of analytical experiments breaks a theory into its component parts and evaluates each proposed process to see if it is true (i.e., theory testing). The theory is "analyzed" by formally or informally deriving predictions from the formal or informal theory and testing them to see if they are true. The research is not interested in what a particular subject will do per se in some particular situation, rather the research is entirely focused on the examination of the theory's ability to predict correctly. If theory A is correct, then the behavior will occur one way whereas if theory B is correct, then the obtained behavior will be different in some obvious way.

An example of the cost of a failure to analyze the predictions of a theory before its widespread acceptance is provided by no less than Ferster and Skinner (1957), who had proposed that with a perfect clock there would be only a single peck in an FI schedule. Subsequent analytical research demonstrated that their

opinion had been erroneously elevated to a law of behavior but was wrong.

Alternatively, as a different example, suppose some theory argues that VI schedules are preferred over VR schedules because a VR requires more pecks than a VI. As an analytical evaluation of this theory, a VI 30-s schedule could be implemented under a green key while a VR schedule yoked to the response counts under the VI schedule could be implemented under a red key light. Requiring the same number of pecks in the VR as had been emitted in the prior VI, equates the number of pecks preceding each reinforcer in the two schedules. Subsequently, the bird could be given a choice between a red and a green key light. The choice would indicate a preference between the scheduled properties of VI and VR other than response counts because the count had been equated in the two schedules. Note that the color preference per se is irrelevant – it is what it indicates about the theory of schedule preference even when the response counts are yoked that is important.

The more central the tested principle is to the theory under analysis, the more important the research. For example, if the research finds that the elements of the theory cannot have the predicted multiplicative relationship because the variance does not change in a multiplicative way when tested, then the analysis is extremely important. However, if the analysis only finds that some coefficient is 1.301 rather than 1.302, then the analysis helped, but not by very much.

B. Synthesis

This aspect of the knowledge gathering helix is the putting together or creation of something. The purpose of synthesis is to assemble known parts into a whole. The result is the production of a complex behavior or an integrated theory or model that correctly demonstrates or characterizes a variety of simple empirical relationships. It is an important stage in the empirical collection of knowledge because it enables those proposals to be tested in order to obtain feedback bearing on the validity of the component parts and the proposed synthesized process by way of the testing of the predictions of that synthesized explicit model.

The analysis phase is the first stage in the construction of an integrated framework of explanation. Synthesis is the second stage. The successfully synthesized results are a step toward demonstrating the validity of the presumed causal mechanism. If you are collecting information correctly and in such a way that you understand it, then you can generate correct theoretical models of the presumed underlying process and you can create or synthesize new forms of the behavior at will.

1. Empirical Synthesis

This type of synthesis is the production of a new specific behavioral phenomenon, made up of well-understood component parts, simply as a test of understanding, or for some practical use (either case validates understanding).

a. Direct Synthesis

This approach proceeds by reconstituting the phenomenon of interest from component parts. This can be in order to prove that the proposed process actually works as proposed, and further to prove that that process was the explanation for the the behavior under question. Its important to keep in mind that proving that a process works as proposed and the the proof that that process is an important component of the behavior under question are different

Example: If the behavior under variable-ratio schedules is thought to be the result of a positive relationship between faster responding and shorter time to food, then explicitly adding that positive feedback function to any schedule (faster responding results in food sooner) should result in faster responding than the same schedule without it. The direct implementation of such a schedule would synthesize a new functional relationship from component parts and would reveal the empirical reality of the hypothetical process.

b. Demonstration with Other Subjects, Apparatus, or Procedures

This procedure demonstrates the correct understanding of the causal factors underlying a phenomenon by demonstrating the phenomenon with other methods. It is typically labeled systematic replication.

Example: A procedure that disrupted stereotypical behavior in bears using food was used to disrupt stereotypical behavior in autistic children using verbal reinforcers.

Alternatively, animal models could be used to demonstrate that language evolves and works the way we think it does. Some lower animal could be taught a language by reinforcing arbitrary behaviors in the same way our theory suggests natural languages are acquired.

2. The Development of a Paradigmatically Consistent Explanation, or Theory Development

This type of synthesis is the creation or synthesis of a new explanation or theory. It is a set of principled statements regarding how things work such that the revised paradigm explains a wider set of phenomena, integrates formally intractable phenomena, and makes successful predictions. It is the primary instantiation of the synthesis component of the research helix because of its impact on the field. The synthesized paradigmatically correct explanation can be relatively specific and narrow or cover a relatively broad range of phenomena. A detailed treatment of what it means to explain a phenomenon is covered in Chapter 8.

a. Prediction

This type of theoretical synthesis demonstrates the correctness of a theory or model for something by making correct predictions based on that theory or model. If all of a model's predictions are supported and no findings are incompatible with

the model, then the model must be considered as true as any other model with the same predictive success. Research would then be aimed at determining an experimental procedure that would result in one outcome if one model were correct and a different outcome if the other model were correct. Such an approach would allow the selection of a single best model rather like the playoff in sports. These procedures are labeled an experimentum crucis

b. Integration of Divergent Phenomena

This type of theoretical synthesis is broader than simple prediction. It demonstrates the correctness of a theory or model for something by showing how that theory can make sense out of numerous phenomena that have been otherwise intractable to explanation.

Example: It was shown that the explanation for credit card debt, flunking out of school, unwanted pregnancy, and substance abuse; were all consistent with the notion of hyperbolic like temporal discounting (a smaller sooner reinforcer is more reinforcing than larger later).

c. General Theoretical Model

This type of theoretical synthesis is the specification of how the phenomenon is thought to be caused and how it is thought to work. This was what Aristotle referred to as a formal cause (Chapter 8). It is the specification of a thing's "implicit form" or meaning through precise metaphors and models. It would include the laws underlying or describing the action. The matching law, behavioral theory of timing, and the Rescorla-Wagner model of conditioning are all instances of this class.

VI. Domain of Applicability of the Research

When a researcher gathers knowledge, they are rarely interested in only applying those results to the exact situation from which those results were originally gathered. Most typically, researchers are interested in generalizing that knowledge to other procedures, situations, or species. The interest could be in generalizing across subjects, across various independent variables, and/or across various dependent variables.

A. Self-Referential Only

In this relatively infrequent case, the obtained functional relationship is applied only to the preparation from which the data was originally obtained, without any abstraction or generalization. The information is applied only to the

same subject, the same independent variable and the same dependent variable. It is a description of what was done and what happened. For example, the research may determine whether Polly the parrot will move to the right or to the left when it is poked on Monday, December 14. This type of question is very concrete. It tends to be interesting to the individual doing the knowledge gathering because of some implicit paradigm or interest of that researcher.

B. Predicting Isolated Treatment Effect

In this the traditional type of research, the obtained information is used to predict the relationship between two specific values of the independent variable when other subjects are exposed to the same conditions. This research obtains a single fact that we wish to generalize to other subjects. For example, we may find that level *x* of independent variable *y* has *z* effect. For example, as is illustrated in Figure 6.1, providing a 5% bonus for meeting a production quota increases production by 30%. The strong implication is that other subjects at other factories will show a 30% increase in production if they are given a 5% bonus. This research also implies (albeit less forcefully) that bonuses of any amount will probably increase production in general by some amount.

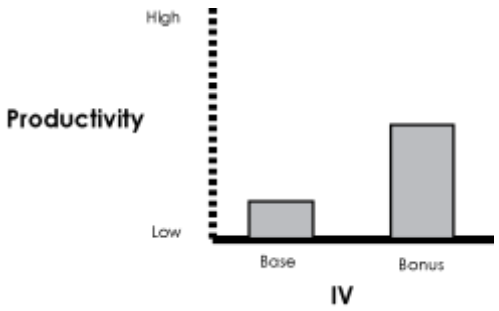


Figure 6.1 An illustration of a typical result of a typical experiment with the independent variable on the x-axis and the dependent variable on the y-axis. The figure shows that the productivity during the bonus treatment was higher than during the baseline.

C. Prediction Across the Entire Range of the Independent Variable

This type of research finding is modeling a functional relationship with an equation. This is typically labeled quantitative research. The task in this type of research is to do enough research to understand how some independent variable works across its entire range. This would require multiple tests with various amounts of the independent variable and the subsequent determination of a mathematical function which would correctly describe the obtained research and therefore predict a dependent variable value for each possible value of the independent variable. In this type of research, the interest is in predicting the behavior obtained with all possible values of the independent variable. Most typically, an attempt is made to describe the effect of all the values of the independent variable with an equation that flows from a presumed process or

theory of how behavior works as a function of that independent variable across the parameter represented by the *x*-axis. As a result, quantitative research is substantially more than curve fitting. An example of the predicted results is illustrated in Figure 6.2.

This latter research approach has come to be labeled the quantitative analysis of behavior (stemming from the fact that a function is able to generate quantitative predictions). Unfortunately, the term quantitative research could be mistakenly seen as nothing more than the opposite of a qualitative analysis of behavior.

Note the difference between the information a quantitative function provides (Figure 6.2) and the information provided by an isolated treatment (Figure 6.1). A quantitative analysis procedure results in a type of knowledge that enables the prediction of the dependent variable at any value of the independent variable. In the example shown in Figure 6.2, there is a diminishing return with larger and larger bonuses. In fact, there is a drop in productivity at the highest level of the independent variable when it exceeds the normal pay

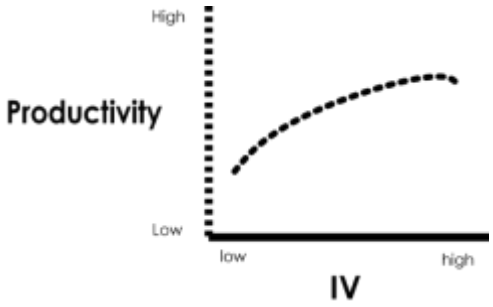


Figure 6.2 An illustration of a typical figure generated by quantitative research. Each value of the independent variable (amount of bonus) is represented across the x-axis with variations in the resulting productivity represented up the y-axis. The figure shows the value of the dependent variable at all the values that the independent variable could take.

A familiar example of a function being used to characterize a data set is a straight line that represents the data in a scatter plot. The linear function is the straight line that minimizes the sum of the squared deviations between the data points and that prediction, and can therefore be seen as the average predicted for each value of the predictor.

Many equations other than a straight line can emerge from a theory. For example, data from a temporal discounting function appear to be best characterized with a modified hyperbolic function.

D. Predicting Across the Widest Possible Class of Independent Variables With the Fewest Restrictions; or "Laws"

The broadest domain of applicability of research knowledge is provided by general principles or laws. In this case, the goal is to predict the behavior of all types of subjects when exposed to any value of the broadest class of independent

variables possible and measured across the broadest range of dependent variables possible. One of the most well-known examples of a general principle or law is the matching law.

A specific research question must be implemented with some specific subject (e.g., pigeon) and some specific procedure (e.g., variable-interval schedule), but from a general principle view the specifics are seen as arbitrary (other than the necessity that the class chosen for the model must accurately reflect the analogous class in the target). For example, the set "subject" in the model is a living pigeon. The set "subject" in the target could include a person, a rat, or a fish but could not include a rock, a dead rat, or a car. The set "reinforce" in the target could include water, a smile, or "success" but generally not a whack on the head or a smelly shoe. In order to assure generality across subjects and independent variables, a variety of each must be evaluated.

General principles have an enormous impact on a researcher's or practitioner's ability to solve problems. People who learn general principles (e.g., "reinforce good behavior") will be tremendously more productive in their interaction with the world than people who only memorized specific solutions ("give Johnny an M&M if he sits in his chair"). With a general principle, the behavior analyst doesn't know just one relationship, but rather what elaborates into millions and millions of specific solutions.

However, there are two gotchas. The first is that learning concrete things is easy, while learning abstract principles is quite difficult. The second gotcha is knowing when and how to apply the general principle. When the principle applies to subjects or independent variables they are labeled "similar" and when they do not apply those variables are labeled "different". The question then becomes how to decide when things are similar and when different. This issue is discussed in more detail in Chapter 13.

A model must be the same as the target with respect to relevant features. It does not matter whether there are similarities or differences with respect to the irrelevant features. In fact, a model is very often used to eliminate some undesired features. For example, we may make a model airplane because the size and cost of a real one make it prohibitively expensive to test in a wind tunnel. Those features of a model of specific interest are relevant. A model of a wing must have the same lift, but the color is irrelevant. A model of a wall color must have the same color, but can be any size, material, or shape.

VII. Conceptual Follow-up: Threats to Meaningful Knowledge

General classes of integrating relationships often relentlessly slip into being treated as if they were accomplished by some internal processes. This error is encouraged by our general cultural view that believes that "causes" of behavior

are always to be found on the inside of organisms. It is critical, however, not to slip into accepting that an **inferred** function relating independent variables to dependent variables is necessarily an **actual internal** process that produces the obtained data. Recall the treatment of knowledge in the previous chapter. We should be satisfied, for example, that a linear model predicts the obtained data, and feel no obligation to presume that there is an internal linear process, or a straight-line processing center in the brain or that a homunculus has a mental calculator which has only an adding and subtraction function to figure out what to do next. The inferential illusion of positing an internal causal process is no less an amateurish error than the illusion that seems to imply that *A* causes *B* when we find that *A* is correlated with our dependent variable *B* or that *B* follows *A*. This malign affliction is well illustrated by how gravity is conceptualized by nearly everyone. If you are holding an anvil and let it go, it will move towards your feet at a predictably accelerating rate of precisely 32 feet per second per second. The termination of its fall can be noted by your scream. Its fall is labeled gravity it is not caused by the process of gravity.

It should be apparent that when various different inferences are applicable to some phenomenon, and those algorithms are not converging on a single algorithm, then, necessarily they cannot all be detailing the same causal process. Rather, at best they are simply arbitrary predictive algorithms that relate inputs to outputs in the same way that there are many ways to skin a cat

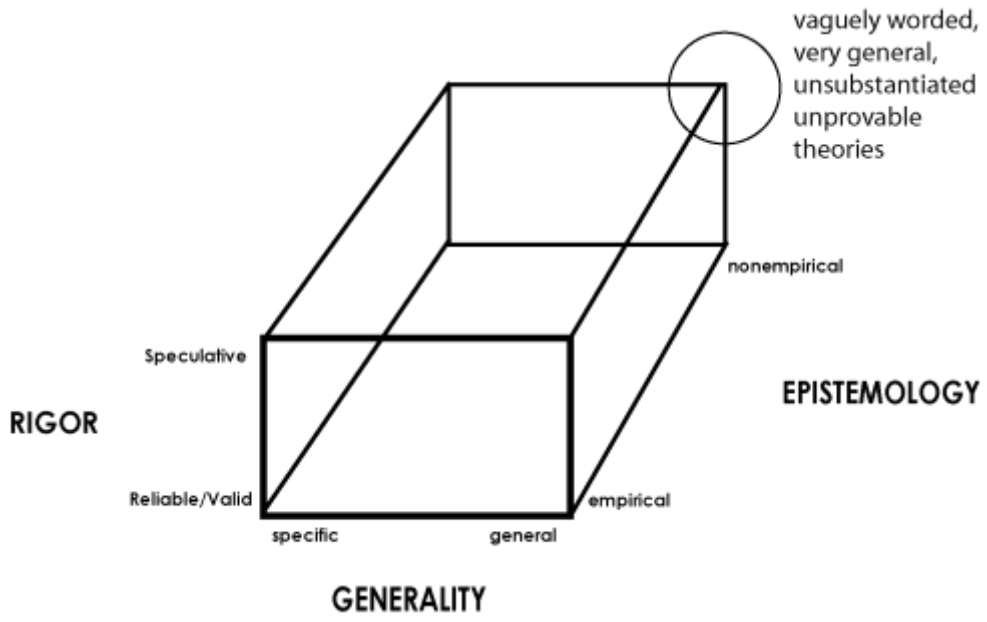


Figure 6.3 The y-axis depicts levels of rigor from reliable and valid to speculative. The x-axis depicts generality from very specific applications to very broadly applicable formulations. Finally, the z-axis depicts empirical formulations in the front and non-empirical formulations in the back.

Figure 6.3 illustrates some of the dimension affecting the meaningfulness of paradigms of behavior. This structure enables a more comprehensive conceptualization of meaningfulness. The y-axis depicts levels of rigor from reliable and valid to speculative. The x-axis depicts generality from very specific applications to very broadly applicable formulations. Finally, the z-axis depicts empirical formulations in the front and non-empirical in the back. The circled portion of the structure indicates the least useful but often the most popular formulation.

CHAPTER 7

Source of Knowledge

I. Conceptual Closure: Referent for "Knowledge" and "Reality"

A. Knowledge
B. Reality
   1. paradigmatic consensus as the only possible referent for real reality
   2. conceivable versus meaningful relationships between paradigmatic consensus and real reality
   3. reality is necessarily dynamic
   4. consistency of research data with paradigmatic consensus or validity

II. Knowledge With and Without Support for Causal Inference

A. Information obtained without manipulation (observation)
   1. procedures
      a. comprehensive observation
      b. restricted observation
         i. restricted with respect to subjects
            (1) case study
         ii. restricted with respect to information collected
            (1) survey
            (2) check sheet
      c. contrived observation (or quasi experiment)
         i. contrived with respect to subjects
         ii. contrived with respect to setting
         iii. contrived with respect to events
B. Information obtained with specific systematic manipulation (experimentation)
   1. review: logic underlying method of differences
   2. review: strategies of experimental procedures
      a. null hypothesis significance tests
      b. behavior analytic research strategies
      c. other methods for obtaining information

III. Source of Knowledge

A. Erroneous attribution of knowledge to transcendental realization
B. Direct empirical experience as the source of knowledge
C. Conceptual precursor: appropriate conceptualization of language
    1. the set of necessarily true properties that can be used to characterize language
        a. stages in productively conceptualizing language
            i. preliminary conceptualization of language: words function as equivalents to things, relationships, or processes
                (1) boundary
                (2) exemplar
                (3) label
            ii. intermediate conceptualization of language: language can control the behavior of others, or communicate
            iii. fundamental conceptualization of language: language is a behavior that is learned
D. Indirect source of knowledge
    1. frameworks for indirect knowledge
        a. decision analysis of communication
        b. classical analysis of theories
        c. source of stimulus control
    2. source of the reinforcing effectiveness of language
        a. impact via common referent
        b. impact via creation of useful sets
        c. impact via matching "reality"
        d. impact via ability to extend understanding into new functional relationships
E. Derived information or inference as the source of knowledge
    1. type of inference
        a. inference based on naive similarity or inductive logic
        b. inference based on formal similarity or deductive logic
            i. logic
            ii. mathematics

CHAPTER 7

Source of Knowledge

The first chapter on knowledge made the case that variance in nature is the problem to which science addresses itself, and understanding covariance, or characterizing behavior under the control of covariance in nature is one of the products of science. The immediately preceding chapter rounded out our understanding of that important product of science. The present chapter elaborates the three sources of knowledge after finalizing our development of the meaning of knowledge and reality. As it was pointed out in the previous chapter, it is important to understand the actual referent for the the various sources of knowledge so that we are not confused and side tracked by their many conceptualizations.

The person in the street often believes that knowledge has four sources: transcendental, direct, indirect, and derived. Each of these possibilities will be detailed in this chapter.

I. Conceptual Closure: Referent for "Knowledge" and "Reality"

A. Knowledge

Each time the term knowledge is used, it's important to recall that the referent for knowledge is either covariance in nature or more correctly stated, behavior under the control of that covariance in nature. If you have a tendency to regress to the laity meaning of knowledge (i.e., something inside the organism), try to repeat its actual referent each time you read the word until that bad habit goes away. If you need the practice, take the time now because sooner or later you will have to automatically know the correct referents for the many everyday words you will be hearing throughout your career without becoming ensnared by their popular meanings.

B. Reality

As a verification of the impossibility of resolving the differences between a really real world and a not really real world, imagine a science fiction world with a brain in a jar and a computer perfectly connected to the brain. The computer perfectly controls visual signals to change as the brain sends signals to the non-

existent feet to walk. The computer controls the "taste" of things "bitten" and even allows the brain to come back to a tree in the winter to "see" the leaves gone. In sum, the computer can completely and perfectly fake "reality" to the brain. The computer can even perfectly control what artificially created "other members" of the scientific community say, so that the experiences of the brain pass all the scientific criteria for truth or reality. In point of fact, the brain in a jar being fed information from a computer, could itself be the result of a more comprehensive computer feeding information to a simulated computer, a brain, and a jar. The infinite regress could be endless. As a result, it should be clear that the notion of a provable real reality is meaningless.

All we can really know is how well our paradigm increases the correspondence: 1) between our direct experiences and the direct experiences of others, and 2) between our explicit theories or models of nature and our and our colleagues' direct experiences, because we can't appeal to any higher authority to prove or disprove that something is what we mean by ultimately "true" or ultimately "real."

When you think about it, reality could never have been anything more than an inference based on experience just as knowledge inside the head could never have been anything other than an inference based on empirical events.

The position taken in this text and by science in general is: what difference does it make whether we are experiencing a real reality or a perfect artificial reality? If the two cannot be empirically separated, then the difference between the two is meaningless and you could just as easily take one side or the other. In the present text, the term "reality" can mean either: 1) the kind of invariance between fundamental relationships expected when things appear by every possible test really real because they <u>actually are</u> really real; and 2) the kind of invariance between fundamental relationships expected when things appear by every possible test really real but that are <u>not actually</u> really real. It's six of one and half a dozen of the other. The important thing to remember is that in either case, the term "real" refers to the invariance between fundamental relationships across time and individuals and nothing more.

1. Paradigmatic Consensus as the Only Possible Referent for Real Reality

Figure 7.1 depicts that multiple interacting scientists operating within the same paradigm have shared knowledge (where knowledge is behavior under the control of covariance in the natural world).

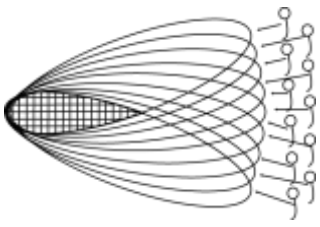


Figure 7.1 This figure depicts various (11) scientists each with a set of experiences (ovals). The figure illustrates with the checkered area the shared experiences of the scientific community which pass the

criteria presented in Chapter 1 (which were labeled understood truth in that chapter). These shared experiences are effectively reality. Sometimes some of the elements in the set can change.

This shared set defines reality. The real world is the intersection of those sets because it is the only thing of which we have a reliable consensually validated measure. Reality is the shared properties in observations across observers, situations, and time and the virtual absence of variance in those shared properties.

2. Conceivable Versus Meaningful Relationships Between Paradigmatic Consensus and Real Reality

Given that we could have either of two different conceptualizations of reality, 1) that there is actually a real reality which exists independently of humans, and 2) that there is invariant shared experiences of the scientific community; it would be useful to formally elaborate the various possibilities that there could be.

Figure 7.2 represents real reality as a gray circle and the scientific community's shared experiences as a circle with cross hatches. If real reality actually exists, it would have one of the five relationships illustrated in Figure 7.2 with respect to the scientific community's reality (defined as the overlapping set of the observations of scientists illustrated in Figure 7.1).

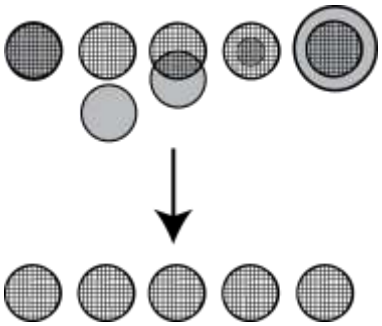


Figure 7.2 Venn diagrams illustrating the various possible relationships between the scientific paradigm's conceptualization of reality (represented with crosshatched circle) and what could be labeled real reality (represented by gray circles).

As previously discussed, because the existence of reality as separate from what we can objectively measure cannot be proven, all of the figures illustrated in Figure 7.2 reduce to the circles with grayed cross hatches as is shown at the bottom of the figure i.e., only invariant shared experiences of the scientific community can be meaningfully discussed and therefore any statements about real reality can neither exceed nor be less than the shared experiences of the scientific community. Note that this view is that a real reality that is beyond (or less than) shared experiences of the scientific community is meaningless and therefore irrelevant NOT that a real reality does not exist.

3. Reality is Necessarily Dynamic

Recall that a paradigm's conceptualization is considered final and the truth until that conceptualization changes. Recall the change in the reality of a great inverted bowl firmament on top of a flat Earth.

The good news is that the hill-climbing algorithm of paradigm change assures that each change in the scientific community's reality is towards a better final conceptualization of reality (i.e., the point where the scientific community's overlapping set ceases to change across the rest of eternity).

4. Consistency of Research Data with Paradigmatic Consensus or Validity

The overlap in the sets of elements and functional relationships documented by the scientific community that are illustrated by the checkered area in Figure 7.1 establishes the entire meaning of reality. That portion of a researcher's data set that overlaps the scientific community's data set is that portion of the researcher's data set that is what is labeled valid or true.

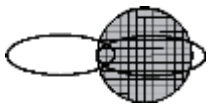


Figure 7.3 Venn diagram illustrating that different people's conceptualization can be different with respect to how much they overlap the scientific community's conceptualization of reality. The crosshatched circle represents the intersection of the scientific community's data as illustrated in Figure 7.1 The right oval represents a person's conceptualization that has a substantial overlap with the scientific community's conceptualization. The left oval represents a person's conceptualization that only minimally overlaps science.

Note however that both scientists and occultists have at least a few data elements that overlap those of the scientific community and are therefore said to be true. The two possibilities are illustrated in Figure 7.3. The relative size of the oval that overlaps the checked gray area defines data as "scientific" and the researcher as a scientist (the right oval which has very few elements outside the cross hatched circle); and an occultist's (only a small segment of the left oval overlaps the crosshatched circle) at the other.

The issue here could also be expressed as how well does the paradigmatic consensus fit what is <u>meant</u> by reality in everyday speech. Some paradigms account for more variance in potential observations that others. As an example, a flat earther could assert that they have a group of people who believe in a flat earth and that their consensus could be labeled reality. Therefore, their view of a flat earth is no worse of a fit to their paradigmatic consensus than the fit of someone with a spherical earth view with respect to the spherical earth paradigmatic consensus.

The flaw in the flat earthers line of reasoning is that the breadth of the observations consistent with a spherical earth paradigm is vastly greater than the narrow set of observations that the flat earth consensus can account for. For

example, a spherical earth consensus would be consistent with the predicted appearance of a ship far out to sea along the horizon, as well as, what we see when we look at other planetary objects. A second issue bearing on appropriateness of paradigmatic consensus pertains to how productive that consensus is in uncovering and developing new predictions and understanding. For example, a spherical earth consensus would predict that if cameras were positioned around the earth above various continents, none of the individual cameras could see all portions of the surface of the earth (the one above North America could not see China) and that all the cameras could see all of the other cameras except for the one on the opposite side of the planet.

II. Knowledge With and Without Support for Causal Inference

A fundamental property of knowledge of a functional relationship is the degree to which it supports the inference of causation. Regardless of the method of obtaining the knowledge, the importance of the ability to make a causal inference, is second only to the properties which make the data a fact and understood

A. Information Obtained Without Manipulation (Observation)

If information is obtained by simple observation of an event, then the set of observations are not sufficient to prove a causal relationship. Therefore, only descriptive statements can be made. Observational techniques take nature the way it comes. As a metaphor, if knowledge were food, observation is getting a meal by going to a restaurant. You get it the way it is served. Sometimes it's useful knowledge that you can use to better understand things, but sometimes it's mixed with confounds which make it impossible to consume.

The task of observational research is one of abstraction of commonalities and the determination of covariance. The researcher comes up with axis labels that show systematic and reliable relationships through correlational techniques. These activities tend to be describing relationships between events and measuring the capacity of the organism.

As with all research, the focus could be on the behavior and functional relations at face value only, or the intent could be to see the behavior as an instance of a more general process.

1. Procedures

a. Comprehensive Observation

This is simply observing nature exactly as it occurs. Sometimes this approach is labeled naturalistic observation. The observer must do those things to assure

that the relevant data are obtained and that the observation process itself did not affect the behavior. Simply watching something in order to see what is going on is relatively unstructured, conceptually demanding, but holds the potential of being very productive.

b. Restricted Observation

We cannot gather information on every occurrence of every conceivable event. In point of fact, comprehensive observation is only a goal. The present category is the explicit recognition that many things that could be observed and documented are ignored.

i. Restricted with Respect to Subjects

(1) Case Study

A case study is an observation limited to a single individual, or to several individuals exposed to generally similar conditions.

ii. Restricted with Respect to Information Collected

(1) Survey

A survey is a collection of a set of information (such as TV viewing habits) by gathering a limited subset of the potential data.

(2) Check Sheet

A check sheet is a collection of a precisely specified subset of variables in a controlled format. It is the most structured and therefore restricted but has the advantage of conceptual simplicity, speed and assurance that the desired information will be included from every individual. Unfortunately, it often tells us little more than we already knew.

c. Contrived Observation (or quasi experiment)

Contrived observations alter the situation. In a sense, experiments could be seen as extremely contrived systematic observations. This category is under the heading "types of observation" when the change is not sufficiently systematic to allow the attribution of causation, therefore it is still nothing more than an observation. If systematic changes are made which allow an attribution of causation, then it is called an experiment.

i. Contrived with Respect to Subjects

ii. Contrived with Respect to Setting

iii. Contrived with Respect to Events

B. Information Obtained with Specific Systematic Manipulation (Experimentation)

Experimental techniques have the intent of justifying causal explanations. Building on the previous metaphor, if knowledge were food, then experimentation is getting a meal by making it have the desired properties by making it yourself.

Gathering knowledge directly through the active manipulation of variables can range from simply "playing around" with variables, to quasi experiments, to actual experiments which can be simple to very complex. On the one hand, actual experiments can document the effects of some continuous series of manipulations such as dose effect curves or parameter documentation. At a different extreme, they could be "crucial" experiments that determine which of several theoretical accounts of behavior are correct. Alternatively, they could involve the deliberate manipulation of interesting variables simply to "see what happens." The logic of experimentation is covered in Chapter 3. Experimental design is also discussed in Chapter 14.

1. Review: Logic Underlying Method of Differences

The task of experimental research is to identify the cause, the whole cause, and nothing but the cause of an effect. An experiment is a method of exposing and understanding the cause of an effect, but it must be remembered that any candidate is not necessarily the true cause. Unfortunately, you will rarely be in a situation where you see nothing but the relationship between some very specific isolated causal input and some very specific isolated behavioral output.

Recall that the approach which isolates just the input and output factors in which you are interested is labeled "the method of differences." It is based on the realization that a comparison with an untreated control condition removes from consideration all factors that are the same and leaves only those factors that are different between the control and treatment (or chance) as potential causes. An obvious illustration of this is giving someone a new pain killer a random half the times they have a headache and giving them a placebo the other half of the times. If the headaches with the new pain killer were less painful than with the placebo, then the new pain killer worked.

2. Review: Strategies of Experimental Procedures

Recall that there are basically two classes of procedures that help extract knowledge from the environment while minimizing confounds and confusion. They were presented in more detail in Chapter 3, and are only reviewed here

a. Null Hypothesis Significance Tests

In group designs or null hypothesis significance tests, the difference in the averages of the resulting behavior of two or more groups (e.g., $\overline{X}_1 - \overline{X}_2$) is the dependent measure. The difference in what the two groups receive is the independent variable.

In Figure 7.4, this is illustrated by ABD being "subtracted" from ABCD which leaves only the independent variable "C." Given the two groups start out equal (which random assignment is assumed to produce), then any difference in the average behavior between the two groups (i.e., $X_1 - X_2$) can be attributed to the difference in how the two groups were treated (i.e., "C") or to chance.

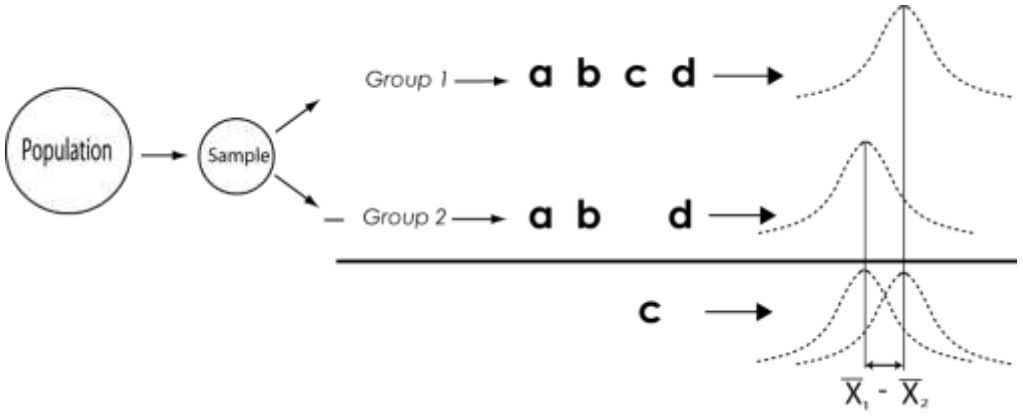


Figure 7.4 A schematic characterization of a two group experimental design. From a population, a sample is drawn. Members of the sample are randomly assigned to two groups. Group 1 receives A, B, C, and D, while the control group receives A, B and D. The distribution of the dependent measures as the result of those exposures are shown in the right end of the figure. The bottom of the figure depicts that the difference in the treatments (i.e., "c") causes the difference in the dependent measures if it was not chance.

b. Behavior Analytic Research Strategies

In single-subject designs or behavior analytic research strategies, the difference in an individual's behavior with and without the treatment is the object of study. The difference in what the individual receives is the independent variable. The difference in the mean behavior after any equilibriation to the procedure is the dependent variable.

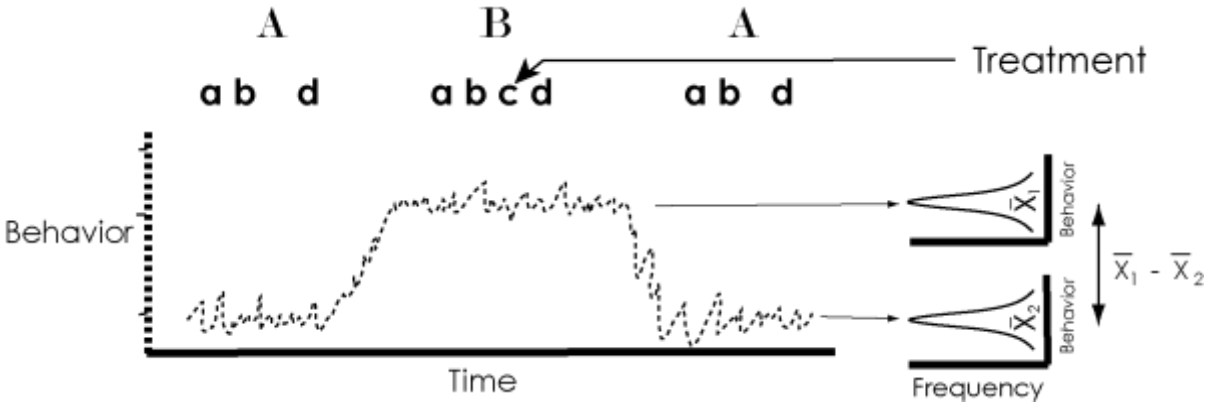


Figure 7.5 A single-subject design. An individual's dependent measure across time is shown in the left frame of the figure. The left most portion shows behavior during baseline conditions (abd) traditionally labeled A. During the treatment conditions (abcd) traditionally labeled B, the dependent measure changes. Following the removal of the treatment (abd) traditionally labeled A, the dependent measure returns to its former state. The right-hand portion of the figure shows the distribution of scores during the treatment (X_1), and the distribution of scores during the baselines (X_2) for that individual. The figure depicts that the difference in the dependent measures is caused by the difference in the treatments, or chance.

c. Other Methods for Obtaining Information

Sometimes knowledge is obtained through experience, which is not the result of typical "scientific" observation or experimental procedures. Examples would be by-products of some technological advancement and accidental or serendipitus discoveries. The task remaining after having the serendipitous insight is to carry out some formal procedure that will clearly identify the potential causal factor and provide the evidence that would demonstrate the covariance in a fashion that other researchers can understand and believe.

III. Source of Knowledge

A. Erroneous Attribution of Knowledge to Transcendental Realization

The attribution of knowledge to transcendental realization is the belief that someone came to correctly understand how something changes as a function of a change in something else because that knowledge just popped into their head. This "source" of knowledge is bafflingly popular.

This first possible source of knowledge (that it just popped into one's head) can be dismissed out of hand. Things do not simply pop into existence. There has never been any evidence to suggest that any knowledge ever just popped into anyone's head. It is always the remembrance of what someone experienced or was told, with the actual empirical source(s) forgotten.

Transcendental knowledge has no consistent relationship with the truth. In fact, it is typically thought to be true regardless of the facts. The acceptability of

transcendental knowledge is best understood when it cuts against you rather than for you. For example, if I told you that I had transcendental knowledge that you were the best person on earth, regardless of the facts, you would consider my transcendental knowledge inspired, but if my transcendental knowledge told me that you were guilty of murder regardless of the facts, you would instantly (and correctly) reject transcendental knowledge.

B. Direct Empirical Experience as the Source of Knowledge

This source of knowledge is coming to understand how something changes as a function of changes in something else because you have direct experience with that functional relationship in nature.

The most fundamental source of knowledge is what a person comes to know by direct personal experience. This would include learning to ride a bike, that something is round, that one thing is bigger than another, that candy tastes good, and that being stung by a bee hurts.

A pencil on the desk can be considered real because we can touch, taste, and smell it. Unfortunately, a naïve reliance on direct personal experience to determine what is real is a bit simplistic. What about errors or misunderstandings? How are we to deal with dreams, psychotic episodes, and drug-induced experiences? What about someone who only hallucinates that a truck is bearing down on them?

Figure 7.6 illustrates direct observation from a decision analysis perspective. It shows what could be labeled reality (i.e. the scientific communities shared experiences) shown in gray cross hatches, with personal experiences depicted with diagonal lines. Direct experience can have both miss and false alarm errors.

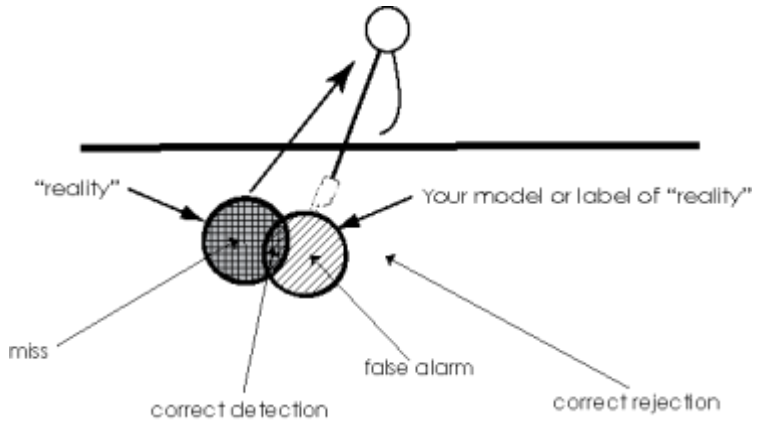


Figure 7.6 A depiction of a person experiencing the natural world as if through a glass darkly (the heavy solid line). A person's direct experience (or model or theory) has some elements that do not change with additional experience has some elements that are eventually removed as the result of additional experience (false alarms), has some elements that need to be added (misses), and has some elements that were not and will not be considered real even with additional experience (correct rejections).

Additionally, what about events that cannot be easily seen, heard, tasted, or felt, such as the temperature of the center of the sun. To review, Chapters 1 and 2, the

scientific community solves this problem of separating hallucinations from facts at the most global level by providing reinforcing consequences for empirical evidence, reliable observations, multiple converging evidence, consensual validation, and operationally/functionally-defined terms, which are all integrated within a paradigmatic framework. Take a moment to look at Figures 7.1, 7.2 and 7.3 again. Recall that "reality" is the overlap in the sets of experiences of the scientific community.

C. Conceptual Precursor: Appropriate Conceptualization of Language

Because in most cases, knowledge is acquired through language we must have a general idea what language is and is not. Anything that can be conceived can be put into words, but that does not make it true. Additionally, we need to avoid being led astray by false realities created by our words or our misunderstanding of what the language means or implies. Bacon was absolutely correct in saying "words can betray their own purposes by obscuring the very thoughts they are designed to express."

The following section is a bare bones presentation of what language is with the mentalistic frills removed in order to understand one of the products of science: knowledge. Our goal is to be able to use the concept "language" without being confused by the inscrutable ambiguity and unwarranted tacit limitations and to not give information gained through language any more credibility than is warranted. Language does not come from the reality fairy. Figure 7.7 depicts the behavior analytic versus the traditional animistic conceptualization of language.

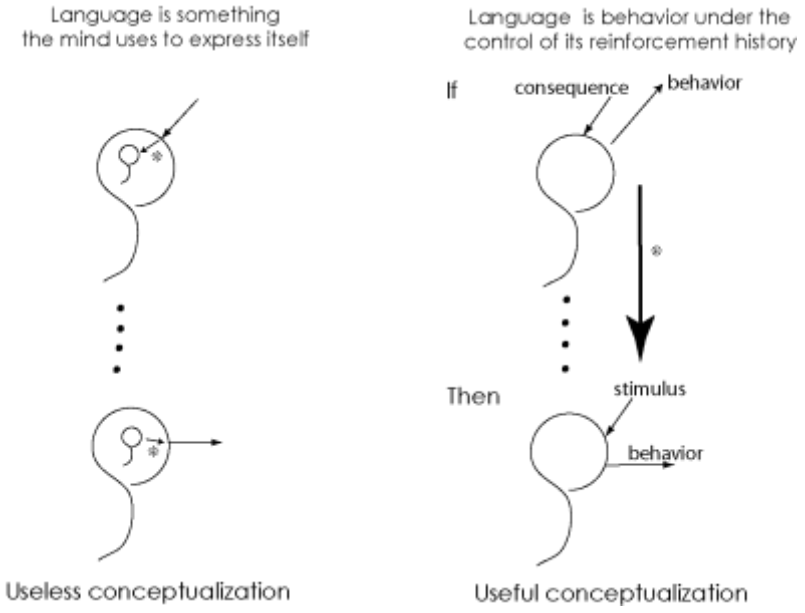


Figure 7.7 The left portion of the figure portrays a typical animistic tautological view of language. The referent for language is designated with an asterisk. It portrays that the mind receives language and speaks with language to get what it wants. The right portion of the figure portrays that language is a result of our learning history with respect to communicating with others. The referent

for language is designated with an asterisk. Saying words is a discriminated reinforced behavior. Reacting to words is similarly best understood as a discriminated reinforced behavior.

The limited task of this section on language is to simply enable us to validly use a semblance of the concept of language to discuss sources of knowledge productively rather than to develop a comprehensive understanding of language. That larger task is well beyond the scope of this text.

1. The Set of Necessarily True Properties That Can Be Used to Characterize Language

No one could possibly doubt that it could be objectively proven that one person could look up a phone number of a pizza parlor in a telephone book and behave in some way that could enable a different person to correctly call the pizza parlor and get a pizza without acess to the phone book.. Humans can easily do it - frogs cannot do it. Language is an empirical fact, but there is nothing that forces the typical layperson's, error-producing approach to language to be our only option.

It has been repeatedly demonstrated that the most productive way to explain something and understand its causes, and characterize its meaning is in terms of the functional properties of objectively demonstrated entities. Language is necessarily, and therefore can best be conceptualized as, a relationship between empirical external behaviors and empirical external events. It may be any of many other more complex or more intangible things but each of those possibilities may be wrong. In the same way knowledge or memory is actually a relationship between objective events in the environment from which inner events are inferred, language is also first and foremost a relationship between objective events in the environment. Therefore, by limiting ourselves to the facts, we can limit our likelihood of being led astray by errors of our own making. It really doesn't matter whether ultimately language is the mind reaching out, brain chemicals, or space aliens. In the absence of proof, all inferences are equally meaningless; all are derivatives of the actual functional relationships between empirical inputs and empirical outputs.

a. Stages in Productively Conceptualizing Language

While the three conceptualizations provided below are all true in some sense, each successive one is more complete.

i. Preliminary Conceptualization of Language: Words Function as Equivalents to Things, Relationships, or Processes

It should be noted that an equivalence view does not refer to an inner person choosing to use some specific word as an equivalent of something else, such as saying "John chooses to use the word "bottle" rather than holding up a bottle."

The equivalence conceptualization of language is based on the fact that if John's verbal behavior pertaining to what objects are on the table is analyzed, it

would be found that saying "bottle" is interchangeable with holding up an actual bottle. The functional properties of saying "bottle" are the same as holding up the bottle. This simplest and most straightforward conceptualization of language is that words are interchangeable with things, processes, or states, or have covariance with them or are associated with them. The physical bottle is said to be the "referent" for the word bottle. Just as the word elephant is equivalent to pointing to a large land mammal with a trunk. Alternatively, being told how to navigate to a location functions as an equivalent to reinforcers occurring for making specific turns at particular intersections.

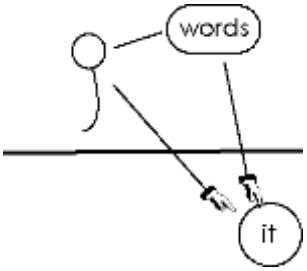


Figure 7.8 The depiction illustrates that words can be thought to point to, or be equivalent to, things in the natural world. Words are said to point to (or be equivalent to) their referents.

(1) Boundary

The first aspect of considering one thing (e.g., a word) as equivalent to a set of properties (e.g., an actual elephant) is establishing the boundary that contains the things that are included and not included in the set and are "pointed to" by the word. They are the word's referent. An essential aspect of the referent for a word is the exclusion of what is not part of the referent. We must have a clear definition of the referent for a word. Male and female elephants both get the label elephant, but rhinoceros are not in the set labeled elephant.

Communication between people requires the common specification of what is and what is not included in the set of interest. For example, the speaker cannot be talking about elephants while the listener is hearing a story about rhinoceroses. This is the point of operational/functional definitions. There are aspects or elements that are the thing and there are elements that are not the thing. Chapter 1 used terms such as truth and reality after carefully and explicitly defining their boundaries.

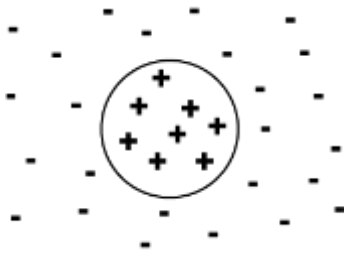


Figure 7.9 A referent is a set containing elements. A plus sign (+) could designate elements within

the set (e.g., elephants) while a minus sign (–) could designate elements not within the set (anything other than elephants).

It's illuminating to consider the difference in how the laity as opposed to the scientific community talk about things. The laity put great store in what they think the words mean and pay little attention to whether the listener has the same set of referents for their words. For example, if an IRA member said "terrorist" he is probably thinking of those "evil Muslims," while being unaware that an Irish Protestant probably thinks of that IRA member himself as the very definition of a terrorist rather than a "freedom fighter".

For example, when "memory" is mentioned at an academic conference, the issues that are discussed most often have to do with the operational/functional definition of the boundary, rather than its label (i.e., the word "memory"). At a behavior analytic conference, memory is simply delayed behavior under the control of covariance in nature, rather than something inside the head. After the smoke from any argument clears, the analysis of memory necessarily begins and ends with covariance in nature, the details of the delay, and the person's behavior; rather than a cognitive process, dopamine receptors, the colors in a PET scan or the transmission frequency used by the space aliens.

Some boundaries are relatively easy to define such as "too heavy" referring to anything that weighs more than 75 pounds;" while other boundaries are extremely difficult to define such as "good things."

Boundaries can be specified by specifying a rule for inclusion such as weight. Alternatively, every element belonging to the set can be provided when only a limited number of elements are in the set such as the starred restaurants in Montana. It is an easy task to define the boundary in these two examples.

(2) Exemplar

An exemplar is only one of the many positive (or negative) instances of a set; and is sometimes erroneously considered the definition of a word. However, a exemplar is actually an insufficient definition because it poorly indicates where the boundary of the concept is.

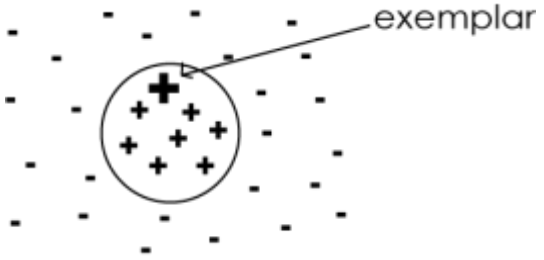


Figure 7.10 An exemplar illustrated with the bold + is an element contained within a set. When the elements within the set vary, an exemplar is usually a "good example" of the members of the set, even if it does not perfectly characterize the boundary.

Simply pointing to an elephant when asked, “what is an elephant?” is not as satisfying an answer as it would seem. The observer may come away with any of a wide variety of incorrect knowledge: the target of the pointing could be the color of the elephant, i.e., the word elephant means “gray” - I want to paint my room elephant. Alternatively, the target of the pointing could be the elephant’s droopy skin, i.e., the word elephant means “wrinkly” - I use Botox so I don’t look elephant; etc.

(3) Label

After the boundary of a thing is specified, then it can be labeled. The label must reliably match the referent across the language culture. In effect the label becomes equivalent to its referent and the label functions as if it were the referent. Possibly the simplest example is the word “NO!” coming to control the same behavior as pain in a toddler. The behavior of a parent shouting “NO!” and the parent striking the child are controlled by the same event, and have the same effect on the toddler.

The comedic routine of Abbot & Costello “Who’s on First” is an excellent example of the confusion that occurs when the label/referent relationship is not common between speaker and listener. A more current example is the “dude” / “sweet” interaction between Jesse and Chester when viewing each other’s tattoos.

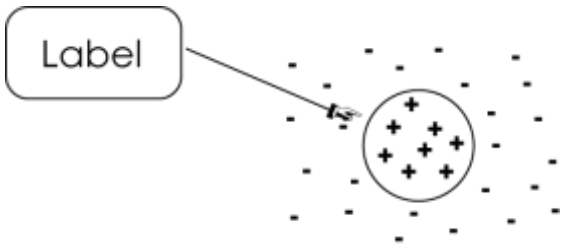


Figure 7.11 A set containing elements can be given a label or words that point to or are equivalent to that set. For example, the words apple pie can be used to refer to a baked pastry containing apples and cinnamon.

The important aspect of the "labeling of things" dimension of language is to point out that stimuli (e.g., large land mammals with trunks) control the same word (“elephant”) in everybody in the same language culture and that that word comes to function as an equivalent to large land mammals with trunks. For example, if someone is exposed to the sentence “if an elephant steps on your toe, it hurts” then that person will likely behave around elephants as if an elephant had stepped on their toe. Exactly which items are in the set and which items are excluded from the set is an issue of great concern. A punctilious concern for the exact referent for a label when variations in referents matter is the motivation underlying operational/functional definitions.

ii. Intermediate Conceptualization of Language: Language Can Control the Behavior of Others, or Communicate

In this second conceptualization of language, language is considered the behavior of one person (the speaker) that controls the behavior of another person (the listener). For example, one person says to a hungry friend "the phone number for the pizza place is 867-5309" and the listener dials that number and successfully gets a pizza delivered, thus reinforcing all the pertinent behaviors

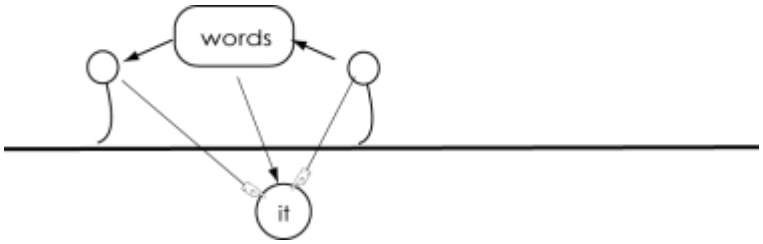


Figure 7.12 A person could emit words that are equivalent to something, a phone number, For example, if another person has the same words being equivalent to the same things, then the emission of those words by the speaker would transfer a functional relationship or knowledge to a listener. The listener could then for example dial the pizza parlor.

iii. Fundamental Conceptualization of Language: Language is a Behavior That is Learned

The most fundamental conceptualization for language is the obvious ramifications of the first two intermediate views of language. It emphasizes the process whereby a series of specific behaviors come to occur in particular situations as the result of being reinforced by the language community and is the critical realization in understanding language.

It is interesting to ponder exactly how someone could be validly reinforced for pointing to an invisible object no one can see. Alternatively how does someone come to validly learn to describe the properties of a thing that cannot be known. Who (or what) would correct the person when they were right or wrong.

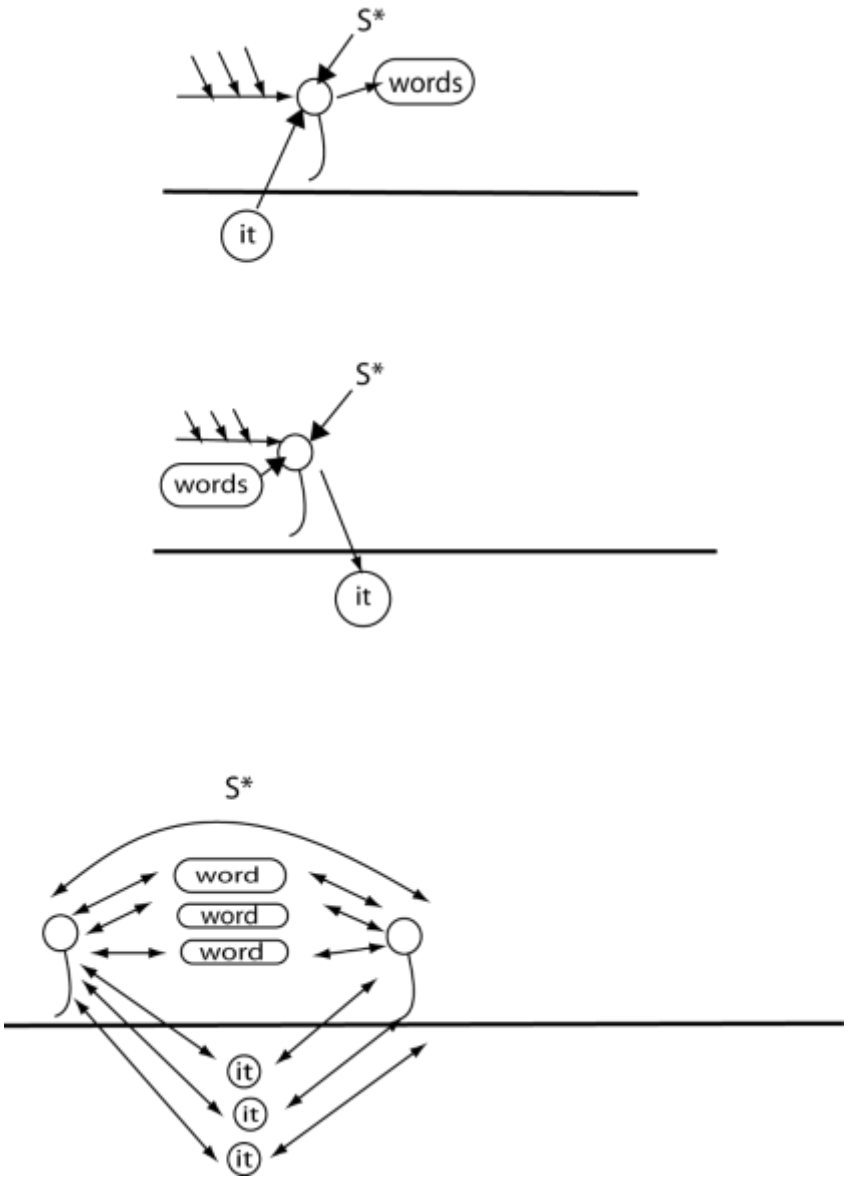


Figure 7.13 The top frame depicts the reinforcement history of someone with respect to the emission of words relating to things in the natural world (e.g., the word elephant for a large land mammal with a trunk). The middle frame depicts the reinforcement history of someone with respect to hearing words relating to things in the natural world (e.g., a large land mammal with a trunk for the word elephant). The bottom frame illustrates two different people with comparable reinforcement histories with respect to saying and hearing (or writing and reading) (common language) in a closed loop. Continuing the previous example: one person could look up the phone number of a pizza parlor and as a result of language, communicate that information to a second person such that the second person could correctly dial it and get a pizza for them both.

Language is a system of stimuli (e.g., hearing words) and behaviors (e.g., saying words) reinforced by the consequences obtained by the speaker and listener. For example, we come to apply the word elephant to large land mammals with trunks, or point to an elephant when we hear the word elephant by virtue of our reinforcement history. It is the reinforcing consequences of communication that control what words and what behaviors are controlled by those words. For

example, if one person says to a hungry friend "the phone number for the pizza place is 867-5309" and the listener dials that number and successfully gets a pizza delivered, then those words are likely to be reinforced by the listener. In point of fact, it is all aspects of language that are learned, the modules we label "words," "speaking," "writing," "grammar," "idiom," and everything else.

This third conceptualization of language clarifies the verbal muddle surrounding private events. Unless one believes that the word-fairy gives people the correct usages of terms relating to private events, one must accept that it is the public aspects of private events that enable us to talk about private events. How else would we have learned when to say, "my tooth hurts" when our tooth hurts? We could have just as easily been taught to say, "I have an ear ache" or "the sky is blue" or "uga mug mug." The figure below illustrates three public behaviors such as crying, holding one's jaw, and saying: "make it stop." Only these types of things can happen in the public world and only these types of public behaviors can be reinforced by the language community.

Figure 7.14 A Venn diagram illustration of the intersection or the common properties of three behaviors; for example, crying, holding one's jaw, saying make it stop.

Simply put, when we verbalize a putatively private event, as "I have a toothache," whatever internal event we are labeling with the word "toothache" can be no more than the common element in multiple public events that we had and then were reinforced for having labeled with the words "I have a toothache." It is productive at this point to ponder how we could possibly teach a child when to say "I have a toothache" if they were encased in a concrete chamber 1000 miles away with only a pellet dispenser connecting the two of you. Simply put, no one can learn to talk about the totally and completely private aspects of private events if they were not in actuality the common component of the public manifestations of that inferred event. The next logical step in your pondering is the realization that the truly private aspect of private events is just as meaningless as the thought that is unthinkable or the color that is invisible. How would anyone learn to communicate to anyone else about an entirely private private event. Exactly what would the language community reinforce?

It's also relevant at this point to reconsider the dolphin metaphor introduced in the preface. The actual referent for the fact that the person actually "sees" the dolphin can only be the set of public behaviors from the person. You cannot observe in any way what the person actually <u>sees</u> even if your PET scan display of their occipital cortex turns green in the shape of a dolphin and red letters spell out

dolphin. Asserting that the color change means the person sees the dolphin is an inference. In reality, the inference based on the PET scan must be validated by a change in the person's public behavior. No one can know what a person actually sees, no one ever did, no one ever will. Ponder for a moment "who" is inside the brain that can see the dolphin-shaped area in the brain through all that meat. How does that homunculus learn to see what part of its brain lights up in the shape of a dolphin and how does it come to know to interpret that shape as a dolphin?

The more correct (and behavior analytic) way of expressing the say-see the dolphin issue is "that person's behavior, both body language, and vocalizations are similar to previous people whom I have observed who could subsequently report on a variety of additional details about the content of the SIRDS without additional prompting on my part. I label that set of behaviors "they see the dolphin," whereas people who simply say the words "there is a dolphin in the picture" without any additional ancillary behaviors have rarely subsequently added additional details about the content of the SIRDS. I label their behavior "they are only saying the phrase "there is a dolphin in the picture they do not actually see the dolphin."

However, that way of communicating the issue is frustratingly laborious (even in the brief version provided) and besides it does not have the same rhetorical snap as "saying dolphin is not the same as seeing the dolphin."

D. Indirect Source of Knowledge

Indirect sources of knowledge provide the understanding of how something changes as a function of changes in something else by way of language rather than by way of your own direct experience.

This second source of knowledge is labeled indirect. It can be gained by receiving information from someone else that actually experienced an event or who got it through some indirect means themselves. In this regard, synonyms for indirect sources of knowledge would be language, symbolic experience, vicarious knowledge, and communication. The example given previously was a person finding out the phone number of a pizza parlor because someone else told it to them. The validity of the transmission is provided by the person answering the phone saying: "Luigi's Pizza Parlor."

1. Frameworks for Indirect Knowledge

a. Decision Analysis of Communication

Figure 7.15 provides a signal detection analysis of a speaker's model of some environmental event obtained through direct experience and the listener's model of that same event obtained through indirect experience from the first person. Note the many potential types of error. Pay particular attention to the bottom block of text labeled listener's decisions in Figure 7.15. Take time to think through an extended description of each one and consider all the combinations such as how a listener could be right with respect to the speaker but wrong with respect to

reality or alternatively, that the information gained indirectly could be more correct than the information gained directly.

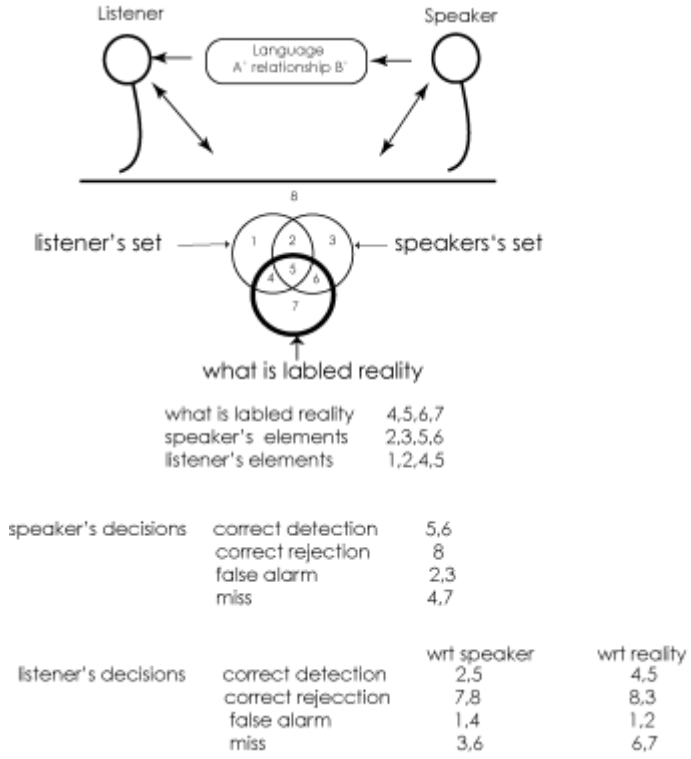


Figure 7.15 An illustration of the overlap, misses, and false alarms in a typical communication. The speaker's set can imperfectly capture the referent and the listener's set with respect to the referent can be slightly different than the speaker's set. The circle drawn with a heavy line represents the set of elements labeled reality. The upper right circle represents the elements in the speaker's set. The upper left circle represents the elements in the listener's set. The various subsections of the circles making up each set are provided in the upper block of text. The second block of text provides the segments making up the various decision outcomes for the speaker's set. The lower block of text provides the circle segments for the outcomes of the listener's decisions with respect to (wrt) the speaker's decisions and with respect to reality.

In general terms, indirect experience can best be understood in terms of the processes labeled reinforcement, discrimination, and generalization. It is the degree to which a behavior appropriate to one situation ("reality") comes to occur by way of other than direct experience (i.e., the words for that situation, relationship, or process). The behavior controlled by the word "dog" or the symbols "2+2" when told to someone becomes equivalent to the behavior controlled by a dog and four objects on a table. Indirect experience acts like direct experience in its relevant aspects. As a result, it makes it possible to respond correctly in a new situation even though the novel situation has never been personally or directly experienced. Someone can tell you a phone number you didn't know, or that a tsunami was coming. In each case, a discriminative stimulus, a behavior, and a reinforcer is involved. The function of the arbitrary stimuli (words) is for the most part equivalent to experienced contingencies with the "real thing."

The important take home message from this figure taken together with the realization that language is a learned behavior in both the speaker and listener; is that there is a lot of opportunities for conceptual slippage and that being aware of them is the first step in not making wrong inferences because of them.

b. Classical Analysis of Theories

There are traditional labels for errors associated with the communication of theories or models of experience. They are illustrated in Figure 7.16. These errors partition the information in the previous figure somewhat differently. There are errors with respect to the proposed processes or rules of the system (syntax) and errors with respect to the rules connecting the theory or model" to "reality" (semantics).

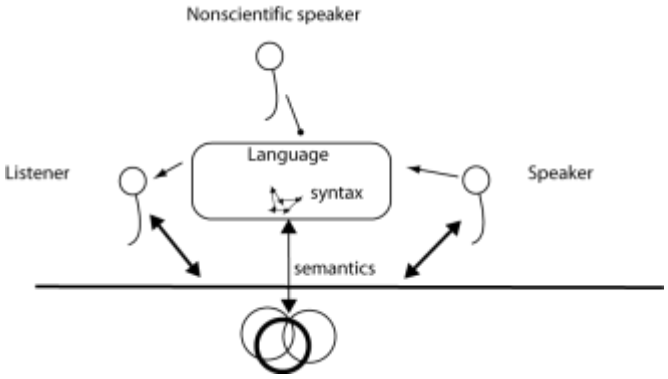


Figure 7.16 An illustration of the two general classes of errors in models or theories of how nature works. Syntax errors are errors associated with the internal consistency of the formulations. The issue here is the explanation, theory, or model consistent with itself and semantic errors are errors in the applicability of the formulations to the natural world. The issue here is what's on paper correspond with what can be directly observed.

Correctly carrying out the math involved in calculating πr^2 is proper syntax. Measuring the radius rather than the circumference is correct semantics. This form of analysis could be applied to Freud's theory of behavior. Simply put it was was a hydraulic one, there were pressures and things bursting out. Freud's syntax was generally correct because hydraulics do in fact work that way. However, his semantics, that is, the theory's connection to the real world, were incorrect. There is no evidence whatsoever that the behavior of living organisms is correctly modeled by a hydraulic system.

c. Source of Stimulus Control

Behavior under the control of verbal experience such as driving to someone's home as a result of being told how to get there is often labeled rule-governed behavior. This source of control over behavior is contrasted with having experienced direct contingencies for the actual behavior of driving and turning.

Labeling knowledge gained through language as rule-governed behavior may be suboptimal. It encourages (but does not force) a focus on an internal

homunculus using the rules to get somewhere, which is the antithesis of a behavior analytic approach. The point of radical behaviorism is to conceptualize functional relationships in terms of the environment and behavior rather than internal entities.

2. Source of the Reinforcing Effectiveness of Language

There are many ways that language can function as a reinforcer and thus support its use.

a. Impact Via Common Referent

Only to the degree that the boundaries, labels, and referents in the indirect system that communicates knowledge are shared by the speaker and listener and are validly connected to the natural world can that system be productive and possibly eventuate in a reinforced response more quickly than direct trial and error experience (e.g., learning the "hard" way). A simple illustration of the reinforcing potential of the establishment of common referents is given by the example of moving to a different country and coming to learn their language. Everyone learns the language they speak for the same reason. If you told someone "get me a glass of water" and they brought you a book, then you would use different words until you got a reinforcing consequence

b. Impact Via Creation of Useful Sets

An important issue with respect to the referents of a word or label is that sets must be "useful" sets. The sets must contain elements that a language community would want to group together for some reason. More precisely stated, this would be "sets must include and exclude entities such that the use of the set increase the likelihood or speed of reinforcement following the behaviors." For example, you may say: "get me something to eat." Something to eat may include a hamburger, a steak or a pizza, but it would exclude a tire, a rock, and a long dead fish. It's relatively easy to see how a language community would create the set "something to eat" by reinforcing the correct use of the term or the correct reaction to the term.

c. Impact Via Matching "Reality"

It could be said that science's task is to assemble useful sets such as compounds (e.g., water) versus mixtures (e.g., salt and pepper), stars versus planets, and the term "reinforcer" versus the term "pleasant outcomes." The task of science is to define the boundaries of words such that the statements rarely if ever have a discrepancy between what is said and what can be experienced. It could be said that this text is to provide its readers with the ability to form sets and labels that enable those individuals to make statements consistent with the scientific community and to perform more productively.

d. Impact Via Ability to Extend Understanding Into New Functional Relationships

It is an interesting fact that words may, in some cases, actually facilitate the mapping of properties and processes into new areas. It would seem that in those cases generalization works more productively when across the equivalent elements (language), then when across the referents themselves (direct experience). The obvious example being that training in math skills makes an individual's skills at dealing with quantitative aspects of nature and predicting nature dramatically better.

There are two strategies to understand how or why knowledge provided through language helps problem solving. One approach looks to the inside of the organism to non-empirical unsubstantiated tautological entities. The second and productive alternative is to examine the empirical relationships between words and things or processes and the factors that make language function better than actual direct experience. This latter approach, or behavior analysis, considers the functional properties of objectively demonstrated entities a necessary and sufficient explanation

The key to understanding the effect of language on the "efficiency" of behavior lies in understanding the properties of stimulus control. When a pigeon's key pecks to a green key are reinforced, the actual discriminative stimulus is complex. Many other aspects of the situation could also exert some degree of control over the behavior. It may be that spatial, temporal, brightness, or other specific relationships may be part of the control over the key peck. As a result, the behavior may spread or generalize differentially to other stimuli along those dimensions.

Words and language provide for even more complex and interconnected discriminative stimuli than key lights, and as a result, have even more complex and more extensive dimensions that can also come to control behavior and be a basis for differential stimulus generalization. This may be the explanation for the fact that following the establishment of language equivalents for empirical experiences people often do better at solving problems.

Much is to be gained by understanding how controlling behavior with words is subtly different than actual experience, not in the sense of simply stating there is actual experience and verbal experience but rather fostering the analysis of what factors control how languages tend to surpass, actual experience, or to fail to perfectly substitute for it. An illustrative example might emerge if how populations with different languages solve particular types of problems with different efficiencies.

E. Derived Information or Inference as the Source of Knowledge

Inference is the term for knowledge based on an individual coming under the control of subtle and complex aspects of their knowledge base such as common elements from several sources which enables generalizing that commonality to some new phenomenon based on its similarity to the known and understood elements. This is illustrated in Figure 7.17. Inference can be based on evidence that was directly acquired, through communication with others, or even through

previous inference. As a result, it appears that the person making the inference came to know something that was entirely new but in point of fact, it is quite the opposite the person presumed that a new thing is the same as the old things.

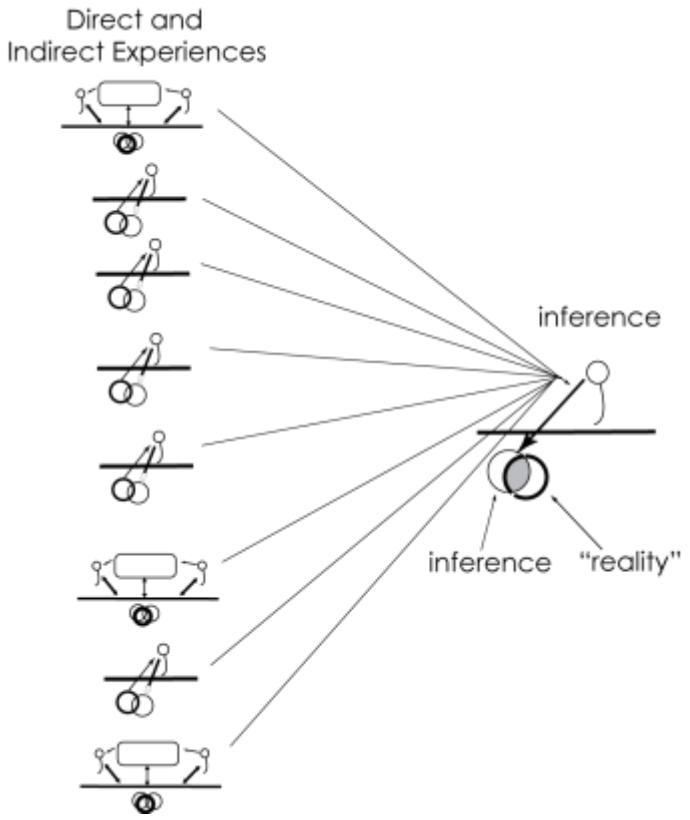


Figure 7.17 An illustration of the factors generating inference. If a person has some number of direct and vicarious experiences (illustrated in the left portion of the figure), then inference is the label for that person generating an estimate of something in the natural world that was never specifically provided in any of those specific experiences. This is illustrated In the right portion of the figure showing some overlap between the inference and reality.

For example, suppose that A works in some particular way because of some factor X [(e.g., key pecks (A) followed by food (X) increase the rate of key pecking)], and B which also has factor X also works the same way [e.g., playing the piano followed by applause increases piano playing], and C which also has factor X also works the same way [e.g., fishing followed by catching a fish increase fishing]. As a result of these common functional relationships a theory or model could be developed such as "a positive" consequence strengthens behavior." Then based on the theory it can be inferred that if D has factor X, then it too will work the same way (e.g., if you follow studying with good grades, studying will increase).

There are many situations where we need information but we can only make an educated guess or generate knowledge by way of inference. This need can occur because no one has measured the unknown, or because the target has an unknown relationship to the original. It should come as no surprise that inference can only be as meaningful as the quality and validity of its predictions and that is, in turn,

determined by the quality of the empirical data supporting the inference, i.e., the validity of the model, the similarity between the original and the target, and the proof of the prediction.

Because inference seems mysterious, there is a strong tendency to bury it at some internal level and to consider it more likely to be right than to be wrong as well as to want to talk about its internal subjective properties rather than come to understand its empirical functional properties such as what experiences make it more reliable and valid. In actual fact, the behavior analytic view is to examine the experienced factors that lead to good and bad inference (i.e., a functional analysis) so progress can be made in understanding the real factors involved in inference and how to make it more accurate. Any internal biological, cognitive, or space alien involvement is irrelevant. Inference is not mysterious when it's considered that if there is a relationship between elements in nature, and if words are equivalent to those elements, then that relationship would also exist between the words.

An inferred formal system that specifies outputs as a function of a wide variety of inputs is labeled a theory or a model. It should be obvious that the task of education is to provide better and more effective inferences.

1. Type of Inference

a. Inference Based on Naive Similarity or Inductive Logic

This source of knowledge is knowledge based on simple informal generalization of events or relationships. An exemplar would be "I don't know why, but it seems like this and this behavior will occur if that and that happens to the subject."

This form of inference is simple inductive logic. Inductive logic is a form of reasoning which proceeds from specific facts to a general conclusion. The specific facts can be simple events like sunrises with the general conclusion being that the sun will rise tomorrow. For example,

The sun came up September 1
The sun came up September 2
.
.
.

.

.

The sun came up September 30
The sun will come up tomorrow

Alternatively, a number of experimental findings can be assembled in a Baconian fashion and become the basis of a general theory which generates predictions via the similarity of its known facts and the target situation of the generalization. For example, an event acted to increase the rate of its antecedent

behavior in these many situations therefore a reinforcer will work in that situation. The similarity is not formalized but rather is the similarity that would be noticed by basically everyone.

b. Inference Based on Formal Similarity or Deductive Logic

i. Logic

This form of inference is deductive logic. Deductive logic is a form of reasoning that proceeds from a known truth or truths to a conclusion that necessarily follows, for example:

All men are mortal
Socrates is a man
Therefore, Socrates is mortal

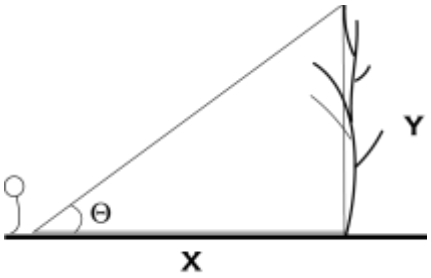
Alternatively, predicted results can be determined from a principled theory that is assumed to be true and considered axiomatic that formally specifies how various elements are to be combined.

ii. Mathematics

Mathematics is a very sophisticated set of verbal sequences or relationships known to work in the past (i.e., "rules") that "solves" problems. It's a fascinating fact that by following a set of rules for manipulating marks on a chalkboard labeled mathematics (that humans "made up") that we could predict events in the natural world that cannot in any way be governed by those marks. The events in nature would have occurred even if humans never existed. Unfortunately, this issue is only mentioned in this section on language, the development of this issue is beyond the scope of this text.

An example of the amazing ability of mathematics to provide useful information is the square cube law. With it we absolutely know for a fact that ants cannot be enlarged 10,000 times and walk around terrorizing Los Angles. We know it for a fact because the weight of a volume (the body) increases with the cube (length times width times height) of its size. On the other hand, the supporting strength of a cylinder (a leg) increases with the square of its cross section (length times width). When any animal is enlarged, the weight of the body will eventually crush the legs. The necessity to have very big legs to support very big animals is readily apparent when an ant and an elephant are compared when both are viewed in identically size pictures. Inversely, the square cube law is illustrated by the fact that we can tell how big an animal is simply by looking at the size of its legs compared to its body. Additionally, we can predict the minimum diameter of legs given the height, width, length, and number of legs of any animal. An interesting side note is that all animals have evolved to have close to the minimal safe leg diameter.

A second example is the use of trigonometry to determine the height of a tree with the relationships (height = x times the tangent of the opposite angle).



$$\tan \Theta = \frac{\mathbf{Y}}{\mathbf{X}}$$

$$\text{height } (\mathbf{Y}) = \mathbf{X} \tan \Theta$$

Figure 7.18 An illustration of an inference that can be made based on mathematics. The height of a tree can be found by multiplying the tangent of the angle to the top of the tree times the distance to the tree.

CHAPTER 8

Explanation

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A. Unequivocally deterministic
B. Understood facts and processes
   1. analogies or metaphors versus understood factual elements and processes
   2. folklore versus understood factual elements and processes
C. Integration within the behavior analytic and scientific paradigmatic context
D. Externalistic
E. Nontautological
F. Functional properties
G. Explicit / unambiguous
H. Minimal error
   1. parsimony in explanations, theories, and models
   2. generality in explanations, theories, and models
   3. conceptual follow-up: optimal tradeoff
   4. quality of prediction
      a. validity of explanations, theories, and models
      b. reliability of explanations, theories, and models
      c. percent variance accounted for of explanations, theories, and models
      d. minimal free parameters
      e. elemental prediction and emendations
I. Principled / testable
   1. confirmable
   2. falsifiable / risky prediction / information transmitted
   3. conceptual follow-up: repercussion of falsification
J. Productive

VI. Conceptual Follow-Up: Terms Pertaining to Explanations

CHAPTER 8

Explanation

The previous three chapters examined one of the products of science: knowledge. The next three chapters examine the result to which that knowledge is put, or the essential product of science: explanation. This first chapter provides an in-depth characterization of "explanation."

Following a discussion in this chapter of the characteristics of an explanation, and how it can be evaluated, the two main classes of explanations relevant to behavior will be detailed in the subsequent two chapters.

I. Conceptual Overview of Terms: Paradigm, Description, Prediction, Knowledge, Cause, Theory, Model, and Explanation

A "Paradigm" or paradigmatic framework is necessary to provide the context necessary for acceptable explanations. It provides the set of things to consider and how things are thought to function. A "Description" details aspects of an event, e.g., the pigeon pecked the key 25 times; or Johnny ran across the room. A "Prediction" is the correct description of something which has not yet occurred, e.g., the pigeon will peck 25 times; or Johnny will run across the room. "Knowledge" is behavior under the control of covariance in nature. It includes covariance as the result of a causal relationship and covariance that is nothing more than two things reliably changing together. Examples of covariance could include the relationship; spider or no spider on the arm and running or not running across the room, or the relationship between the mean weekly atmospheric temperature and the number of children attending school. "Cause" specifies the necessary or sufficient event or events that preceded the resulting change in behavior across levels of molarity and time scales thought relevant to the paradigm. Most typically (but not necessarily), in behavior analysis, cause is constrained to either the events immediately preceding the event in question: i.e., immediate time scale organismic adaptation e.g., because the spider fell on his arm, Johnny ran across the room; or short time scale organismic adaptation e.g., because Johnny studied for the test, he got the answer right. "Theories" or "Models" are formal sets of rules that are thought to produce outputs like the empirical system of interest. Theories or models can be analogical, graphical, logical, mathematical, mechanical, or algorithmic. While theories and models are

often used interchangeably, most typically theories are more general and less specific while models are most typically very specific specifications of what will happen in specific situations. A bit too simplistically put, a theory is a story about what and why something will happen, while a model is an equation that specifies exactly what will happen with each specific change in each of its parameters. Often theories or models are also the formalized system a researcher uses to explain existing data in addition to deducing or inferring hypotheses about further phenomena. While most typically, theories and models start with elements and processes and predict data; explanations start with data and provide elements and processes. "Explanation" is more than knowledge and more than the simple immediate cause of something and more than a theory or model. Explanation is the specification of the paradigmatic context including the boundary of relevant elements and the formally defined general processes thought to account for all phenomena within a given paradigm. It also includes the information needed to generalize the effect to other situations, make predictions, and control or synthesize the functional relationship. Additionally it provides the relevant necessary and sufficient conditions underlying the causal functions of interest.

II. Conceptual Precursor: Preliminary Overview of Causation

A. Aristotle's Conceptualization of Types of Cause

Understanding the functional properties of a causal relationship is an essential element of science and a fundamental purpose of an explanation. There are many schemes for conceptualizing controlling or causal variables. One of the most frequently cited is Aristotle's. He proposed that there were four classes of causation: formal, final, material, and efficient. While Aristotle's conceptualization is sub optimal it is important to understand so that you can communicate to someone who uses his framework.

The following figure illustrates the meaning of his terms. In this example, we are conceptualizing the open-ended cause of a key peck rather than the open ended cause of a woodsman chopping down a tree as Aristotle had used used.

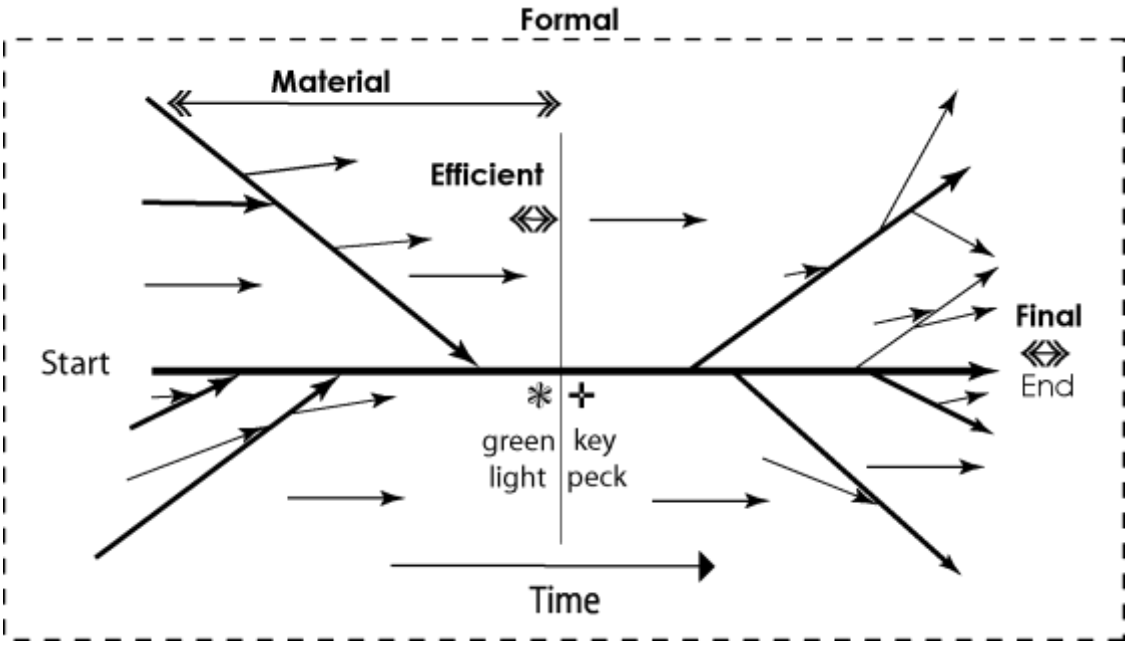


Figure 8.1 An illustration of the various causal factors contributing to the green keylight illumination and the subsequent key peck as conceptualized by Aristotle. Events earlier in time are further to the left. Events following the key peck are illustrated to the right of the figure. Events following later in time are further to the right.

Suppose that the flower (*) in the above figure indicates the moment in time that we turn on a green light that a pigeon then immediately pecks. The peck is designated with a ✚. In behavior analysis this is labeled an immediate time scale organismic adaptation.

Suppose further that the spreading tree-like function to the left of the green light going on (flower) indicates how all the component elements of the relationships preceding the green light and the pigeon key peck come together to cause the key peck. Tracing them backwards in time, we can see how earlier events came together to cause the cause of the peck to the green light (e.g., the invention of electricity and the bird's reinforcement history). Looking back in time, these antecedent events would tend to multiply and become more complex as they further precede the green light going on, very much as parents, grandparents, and great grandparents diverge as they are further removed from a child. In principle, these events could be traced back to their common origin in the big bang, so presumably at some point in the remote past, the diverging lines come back together in the single initial instant of the "big bang".

Suppose that the spreading tree-like function to the right of the key peck (✚ sign) indicates how the things caused by the key peck change as the result of additional environmental events to the end of time (e.g., the experience of pecking causes the pigeon to peck better next time, or enables the experimenter to publish a paper). This is very much like the way children, grandchildren, and great grandchildren diverge as they are further removed from the parent, going downstream from the parent. All of these eventualities have at least one thing

in common in the remote future. As a minimum, they all will participate in the single "big crunch"; and therefore these diverging lines would come back together at the final instant of the big crunch.

But back to the specific case in point - the green light going on and the key peck. To be more precise, the entire set of lines diverging backward in time to the left from the light and forward in time to the right of the key peck and should be illustrated with nearly infinitely complex and nearly infinitely diverging tree-like lines, and be surrounded with a nearly infinite number of parallel lines; but in order to keep the illustration manageable, for the most part, simple relevant paths are illustrated. The paths that are necessary for the key peck following the green light going on and the path that depend upon the key peck to the green light are emboldened.

The overall figure forms the context within which the various Aristotelian causal elements exist. Note that the whole function extends across all time rather than for just a few minutes or a few eons. If time is bounded, then the full function extends from the beginning of time to the end of time; if time is unbounded, then "start" and "end" have no meaning.

In sum, we have a graphical depiction of all historical and future cause effect relationships relating to our green light and the subsequent key peck that depicts the complexity of the issue of causation.

1. Aristotle's Formal Cause

A formal cause is the specification of all of the "laws of nature which result in the key peck to a green light" (as opposed to laws applicable to what makes a dog run from a kick or what makes a chair a chair). The formal cause would include reinforcement, evolution, Ohm's, and Wein's, law plus all the laws that pertain but of which we are not yet aware into one super law. Parts of the "theory of everything" that would never pertain to the light and key peck are therefore not part of the formal cause of the green light causing the key peck.

The elements Aristotle labeled the formal cause can be seen as an essential element in the paradigmatic context necessary for an explanation and generalization of the phenomenon, because it is the rules that are relevant to the cause effect relationship.

2. Aristotle's Final Cause

A final cause is the specification of the end to which the cause "is directed." This cause appears to be the least thought through of Aristotle's causes. Its label as the final cause suggests that it is the end or goal of a thing, and is temporally positioned after the effect, yet it is considered a cause.

If Aristotle meant that the final event was the cause of the earlier event, then final cause is a teleological cause and is impossible. Things in the future cannot reach out back into the past. It would be saying that the pigeon pecks the green key in order to get food. The fact is the actual "getting of food" cannot possibly be labeled a cause because it occurs after the effect. This teleological fallacy can be easily illustrated by an example. Simply expose a naïve food-deprived pigeon

that has not had prior experience pecking which is followed by food to an FR 500 and see if it pecks in order to get the food (if the final cause is reaching back in time the food-deprived pigeon will peck 500 times to obtain food. The fact is the pigeon will starve to death thus proving that final causes cannot cause behavior. The teleological illusion is quite strong and Aristotle may have fallen prey to it. If so, then final cause is, in point of fact, nothing more than those events and processes that precede the cause, which taken together lead to an activity given some conditions (i.e., they are part of the material cause).

A different interpretation of the meaning of "final cause" could be, for example, that Aristotle wanted to differentiate chopping down the tree and subsequently using the wood to cook a meal versus using the wood to build a house. The actual cause in those two cases would be the woodsman: 1) being hungry while on the way to the tree plus a past reinforcement history of cooking with wood or 2) cold and wet from having no roof over his head plus the past experience of alleviating those conditions by building a shelter. In both of those cases the cause actually precedes the result.

This focus on "what is the reinforcer that built the behavior" is a useful piece of information and is an event that follows the current expression of the behavior. However, its actual causal effect preceded the behavior. It is strange that Aristotle did not differentiate the necessary distinction of his argument from teleological nonsense if he were well aware of the fallacy. He could have made what he labeled final cause just another class of material causation.

There are two other types of error that could occur as the result of a focus on the last event of a series. Nothing suggests that Aristotle made one of these errors but they are worth mentioning. An additional potential flaw in emphasizing a particular event at the end of a series as a cause is that this category has no meaning other than, that it is the rightmost point of the function segment being considered. After all, there could be some later event that could be said to be the final cause of both cooking a meal and building a house such as "raising a future family" for instance. Secondly, a final cause view often mistakenly presumes that things get better and better over time and therefore the last event (the goal) carries special significance because it is thought to be the best condition of all that went before. Rather, the reality is, things change until they stop changing.

3. Aristotle's Material Cause

Material cause is often translated as "that from which something is made. This is most often seen as referring to physical things such as proteins and copper wire, but it could also refer to historical events which made something be what it is; such as key peck training as something that made the pigeon behave as it does, and the discovery of electricity as an event that enabled electricity to be used.

To be most systematic, the current conceptualization considers the material cause in terms of functional relationships across all levels of molarity and all time scales. This would include the levels of molarity of the physical elements involved, and the time scale of historical events affecting those elements. This would also

include all those higher order elements that led to the experiment with the green light being done

4. Aristotle's Efficient Cause

An efficient cause is the event immediately preceding the outcome as opposed to all earlier causes back to the beginning of time. It is the immediate propelling factor that sets an event into motion. In the present example it is the onset of the green light.

B. Issues Underlying the Demonstration of a Causal Function

1. Necessary or Sufficient Causal Factors

The first step in the establishment of a causal relationship is the reliable control of the event. For example, if you flip a switch up and a light comes on and flip it down and the light goes off, then you're well on your way to establishing that the light switch causes the light to go on. In this extremely simplistic situation, a few flips and you and your family's history of it always working that way is sufficient to establish that the light switch caused the light to go on. In simple terms the point is to provide a proof of causation that is acceptable to a fair minded theoretical opponent.

a. Dependency on Correctly Isolated Causal Element

The cause of an event could be only one of several factors in a common grouping of elements. Suppose for instance that each time it rains, cows lay down. It is possible to argue that if we removed the humidity increase that inevitably occurs when it rains then we would find that, in actuality, it was the increase in humidity not the rain per se that actually caused the cows to lie down. To the degree that the group of potentially causal elements is virtually inseparable, then this argument is clearly sophistic and must be rejected on purely pragmatic grounds. However, if the elements are easily and often separated, or if there is interest in manipulating the minimal set of causal factors such as only increasing the humidity in order to get cows to lie down, then the assertion keeps us focused on finding the most parsimonious explanation possible.

Alternatively, the cause of an event may be a relationship other than the relationship presumed. For example, if a pigeon pecks an 8 cm diameter circle but does not peck the alternative 4 cm circle, it could be said that the behavior was caused by the 8 cm circle. When tested with an 8 cm and a 16 cm circle, the pigeon may peck the 16 cm circle and not the 8 cm circle. This “unexpected” result would indicate that the relationship of the circle (i.e., larger) caused pecking, not the absolute size of the circle (8 cm). This result was the foundation of the “transposition” controversy in early experimental psychology. The first conceptualization of a causal factor is not always the correct choice. The actual causal relationship must be experimentally proven in a broad variety of contexts

b. Classes of Causal Effects

i. Onset/Offset

One type of outcome is to cause an event to occur or terminate. For example, hitting oneself on the thumb causes one to change from being silent to yelling. The causal relationship between hammer blows to someone's thumb and them yelling can be easily demonstrated experimentally.

ii. Modulation

A modulating influence is a factor which can alter characteristics of a behavior but which does not necessarily turn the behavior on or off. While hitting oneself on the thumb with a hammer may be seen as the cause for screaming out loud, the words selected to articulate the exact nature of the unhappiness is modulated by the people around. Simply having your peers around or your mother around (without hitting your thumb) does not cause you to yell out anything, but exactly who is around when you hit your thumb modulates what you yell out.

Clearly the behavior following the thumb trauma can be seen as a single class of behaviors modulated by the environment or as entirely different behaviors that occur or do not occur as a function of the environmental context. For example, hammer plus friends results in behavior A; hammer plus mother results in behavior B. The concept of the modulation of behavior is extraneous in this latter case.

c. Conditional Causation

Sometimes an effect will occur, sometimes it may not occur. Sometimes an event will cause an effect, sometimes an event may not have an effect.

i. Sufficient Cause

A sufficient cause is one which is capable of causing an event to occur but which is not essential to its occurrence. A match, candle, and spark are each sufficient to ignite gasoline but none are necessary. Explicitly shaping a pigeon to peck a green key is sufficient to make pecking a green key happen but not necessary for it to occur, the key peck could occur for other reasons.

ii. Necessary Cause

A necessary cause is one that is essential for an event to occur. Oxygen is essential for gasoline to ignite and burn, however, it is not sufficient. Life is necessary for the pigeon to key peck, but it is not sufficient.

d. Dependency on Typical Context

The inference of necessary and or sufficient causation implies some frame of reference. For example, if the frame of reference is allowed to change without

limit then establishing the sufficiency of some element is problematic. In establishing light as sufficient to elicit pupillary contraction in an animal it is presumed that the range of conditions does not include living and dead animals. Simple pragmatic expedience requires the acceptance of a typical context.

e. Paradigmatic Narrowing to Factors of Interest

The cause of a result could be considered to occur at a wide variety of levels of molarity and time scales. When considering a green light and a key peck; in principal, the context could be anything from the quantal cause of light to the cause of life on earth. Productive discussion requires the limitation of the possibilities to factors of interest. As previously presented, the task of resolving all possibilities is insuperable. The Behavior Analysis paradigm for the most part, reduces the task to the simple phenomenological occurrence of the stimulus and the simple immediate time scale organismic adaptation of the objectively measured operant.

i. Molarity Level of Physical Cause (One Dimension of Aristotle's Material Cause)

This is the specification of the physical elements making up all the components involved in the change in the cause and the change in the result. In the present example, this would involve both the physical elements underlying the pigeon and the physical elements underlying the green light. For the most part, the physical elements involved in the green light as well as the pigeon, are ignored in Behavior Analysis. A conceptual scheme for the integration of various levels of molarities was presented in Chapter 4.

Existential Adaptation involves the adaptation of existence itself (more precisely, the strong force, the weak force, electromagnetic force, and gravity). Atomic Adaptation involves the adaptation of atoms (more precisely, atomic structure or the statistical positioning of electrons, protons, and neutrons. Cellular Adaptation involves the adaptation of cells to changes in the environment. Organismic Adaptation involves the adaptation of the behavior of a whole life form. Group Adaptation involves the adaptation of a group (more precisely the change in the proportion of a population responding to some event in the environment).

ii. Time Scale of Historical Cause (One Dimension of Aristotle's Material Cause)

This is the specification of the historical exposures affecting all the components involved in the change in the cause and in the change in the result. In the present example, this would involve both the exposures involving the pigeon and the exposures involving the green light. The processes involved in an exposure that changes a thing can vary across a very wide time scale. For example evolution has a very much longer time scale than a reflexive response to an elicitor and the

creation of a solar system takes longer than it takes photons to leave a bulb. For the most part, the exposures involving the green light are ignored in Behavior Analysis, while the exposures involving the pigeon are of great importance. A conceptual scheme for the integration of various time scales of adaptation was presented in Chapter 4.

The time scales pertinent to the behavior of an organism are: Immediate time scale adaptation which extends from milliseconds to seconds as exemplified by a key peck to a green key; Short Time Scale adaptation which extends across the seconds to days time scale as prototypically illustrated by a pigeon learning to peck a red key and not to peck blue one; Medium Time scale adaptation which extends across the days to years time scale as prototypically illustrated by an organism "learning to learn"; and finally, Long Time scale adaptation which extends across the years to millennia time scale as prototypically illustrated by the evolution of a characteristic in a species

III. Conceptual Overview: What is an Explanation?

With respect to a functional relationship, an explanation makes sense of that finding. To do that, it must provide:

1. Epistemological rules to separate elements that are acceptable from those that are not (e.g., what are labeled empirical findings in science)
2. The subset of all possible things that are of interest to the paradigm (e.g., the elements involved in short time scale organismic adaption in behavior analysis)
3. The necessary and sufficient factors at the relevant levels of molarity and time scale that result in the cause of the phenomenon under consideration (e.g. a key light going on in behavior analysis)
4. The logical and formally defined classes of functional relationships or processes thought to account for all phenomena of interest (e.g., reinforcement and stimulus control to behavior analysis)
5. Sufficient information to enable understanding the phenomenon in its context (i.e., the ability to generalize the effect, predict it, control it, and to synthesize it)
6. Enough proven functional relationships to consensually validate the processes and their rules of application (e.g., the innumerable examples of reinforcement to behavior analysis)

A. Paradigmatic Delimitation of the Explanation

With unlimited boundaries even the explanation for a light going on with the flip of a switch could be hundreds of millions of pages long.

1. Epistemology

At its broadest, an explanation would have to consider the possibility of ghosts and space aliens being importantly involved in everything. On the other hand, science requires empirical entities and an acceptance of empirical determinism. Explanations can be limited to the paradigmatic framework of science.

2. Domain

At its broadest, explanations could be open ended and cover every possibility in the domain of science. All levels of molarity and time domains would have to e included in every explanation. This would be an impossibly large task. A complete explanation would have to detail every level of molarity down to quantum physics and every time scale and across all time. Most typically only a single level of molarity and a single time scale are considered pertinent. In fact most of the elements within that molarity and time scale are taken for granted.

3. Type of Covariance

At its broadest, all covariance must be covered in an explanation. On the other hand, because explanation typically implies causation, only causal relationships are considered relevant. An explanation is typically limited to only factors pertinent to causal relationships.

It is critical to separate events that simply happened to occur before the occurrence of the dependent variable from actual causal variables in an explanation. For example, simply because a car pulled up to Johnny's house and then Johnny ran home does not mean that the arrival of the car explains why Johnny ran home. It could have been that a spider had climbed up his leg. It is for this reason that an explanation requires: 1) a true causal event with multiple converging support and that 2) it is unacceptable to simply note some event that preceded the result as the explanation, or explain a result with its own data.

4. Paradigm of the Field

The scientific study of organismic adaptation encompasses several paradigmatic approaches each delimiting explanations according to its own paradigm. The most notable being behavior analysis with its focus on short time scale organismic adaption, external functional relationships, and the importance of the the consequence of behavior.

5. Local Context or Specific Research Area

Explanations are typically further delimited by the very specific research question. Investigators using the method of differences limit the potential causal factors to the differences between the procedures. This approach also limits the task of the explanation.

III. Conceptualizations of an Explanation

An explanation of an event allows us to understand that functional relationship and: 1) to not be surprised by the occurrence of that relationship given the situation, 2) to be able to generalize it, and 3) to be able to predict the relationship in new situations.

In the final analysis, the explanation for an event is the complete extended cause or the characterization of all the processes involved; the paradigmatic context of the causal factors; and the multiple converging evidence supplied by other phenomena pertaining to the same functional relationship. The present treatment will detail explanations from four perspectives: 1) explanation focusing on causation, 2) explanation focusing on multiple converging support, generality, and prediction, 3) explanation focusing on sources and types of error, and finally, 4) explanation as a metaphor. All the elements are the same in each case, only the framework within which they are presented changes. If one of the four perspective of "explanation" doesn't work for you, maybe one of the other three will make all four make sense to you. In any event, all four will help you develop a robust understanding of an explanation and be able to separate good explanations from poor ones, and to be able to construct effective explanations.

A. Focus on the Chain of Causation Underlying Explanations

To illustrate the conceptualization of an explanation as a cause, we can take as the case in point the Aristotelian example used in the initial discussion of causation presented earlier in this chapter. In that case, a green light was illuminated and a pigeon immediately pecked it. The Aristotelian cause figure is re-presented below as Figure 8.2. This figure illustrates an explanation as a cause and recalls the many terms relating to causation.

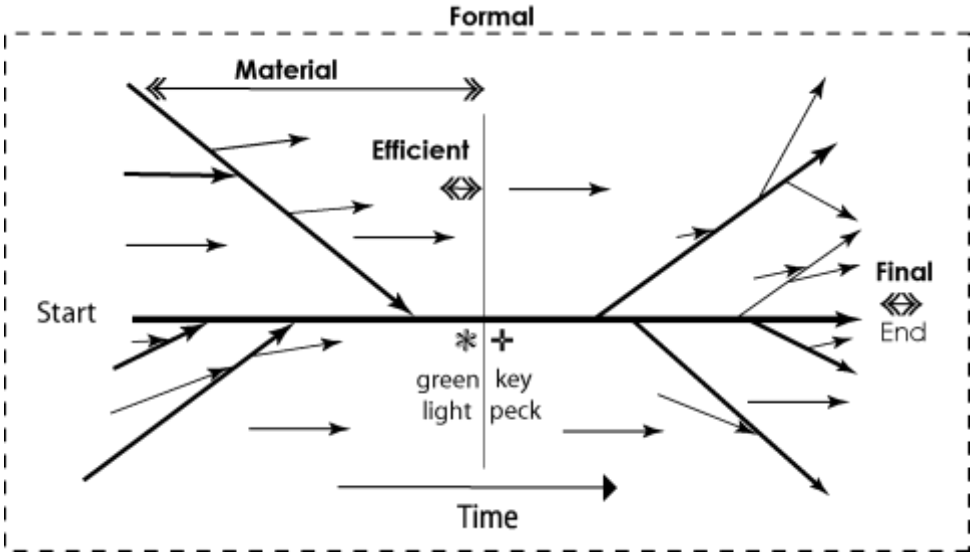


Figure 8.2 A re-presentation of Figure 8.1 for convenience. An illustration of the cause/effect relationships contributing to and ensuing from an event such as a key peck immediately following the key turning green.

Explanations can be seen as very broad "if cause then effect" statements with the paradigmatic context or formal causes which enable generalization of the relationship to other situations. For example, the total explanation for the key peck to the green keylight going on is all the Aristotelian, time scale, and level of molarity causes pertaining to pecking the green keylight. These would include the evolutionary and reinforcement history of the pigeon, as well as all the quantal, chemical, biological, and organismic processes involved. The total formal cause is also appropriate for an explanation because it provides for the validity of the explanation and the rules by which the cause-effect relationship can be generalized or modified. Most typically, only a few components of the total formal cause provide the vast majority of the functional properties useful to generalize and predict the effect in most research and applied situations. This removal of the redundant or inapplicable elements is often accomplished with the method of differences.

1. Conceptual Precursor: Method of Difference

This conceptual precursor would be lengthy and would therefore blur the focus of this chapter. This is an unacceptable cost if it is unnecessary. The important element is: the difference in what is done causes the difference in what happens (if you eliminate chance). An extended treatment of the Method of Difference is presented in Chapter 3. If you are not now fully comfortable with the meaning and implications of the method of difference, take a moment to review that material at this time.

The method of differences parcels out the differentiating factors in a procedure for consideration as causal. It also isolates these factors as fundamental components of the explanation in that causation is closely tied to explanation.

2. Determining Simple Cause Via Simple Method of Difference

Figure 8.3 below illustrates the explanation of the key peck as the difference in the procedures (i.e., light going on). In this case, our focus is on explanation in terms of immediate time scale organismic adaptation (i.e., the pigeon "reacting" to the green key light) and at a relatively shallow depth (i.e., little beyond the simple effect of the light going on).

In some other case the independent variable could be across some other time scale (e.g., evolution and reproductive success rather than a light going on) or could be across some other level of molarity (e.g., activity in the motor cortex rather than a light going on). In those other cases the baseline and treatment conditions would be different

Figure 8.3 presents an A-B-A; baseline, treatment, baseline design, method of difference experiment. In the method of difference, the individual is exposed to two different conditions. Any difference in what the individual does is attributable

to the difference in what that individual experienced or chance. The upper frame illustrates the procedure: the light is OFF, then ON, then back OFF. The middle frame illustrates the obtained behavior. The bird is doing nothing then it pecks, then it does nothing again. This frame illustrates the time course of a single peck. The bottom frame characterizes the process in a semi-algebraic notation.

Consider the upper frame: various events are occurring in the baseline phase. An arbitrary subset of all of them is depicted by the letters in the upper left portion of the upper frame. The pigeon is at 80% body weight (D), it is handled every day (E), it is in a chamber (F), and white noise is on (G). These are labeled D, E, F, and G. During the treatment or B phase, the light is turned on (H) so the pigeon received D, E, F, G, and H during that phase. The return to baseline has only D, E, F, and G again because the light is off.

The next lower frame depicts the obtained behavior. Again, an arbitrary subset is illustrated. Consider that during the initial baseline condition the pigeon breathed (P), accommodated its eyes (Q), flapped its wings (R), and turned (S). These are labeled P, Q, R, and S. During the treatment phase, the pigeon also pecked the green key (T). In this case the obtained behavior was P, Q, R, S, and T. When the baseline was reinstated, the peck did not occur and only P, Q, R, and S occurred.

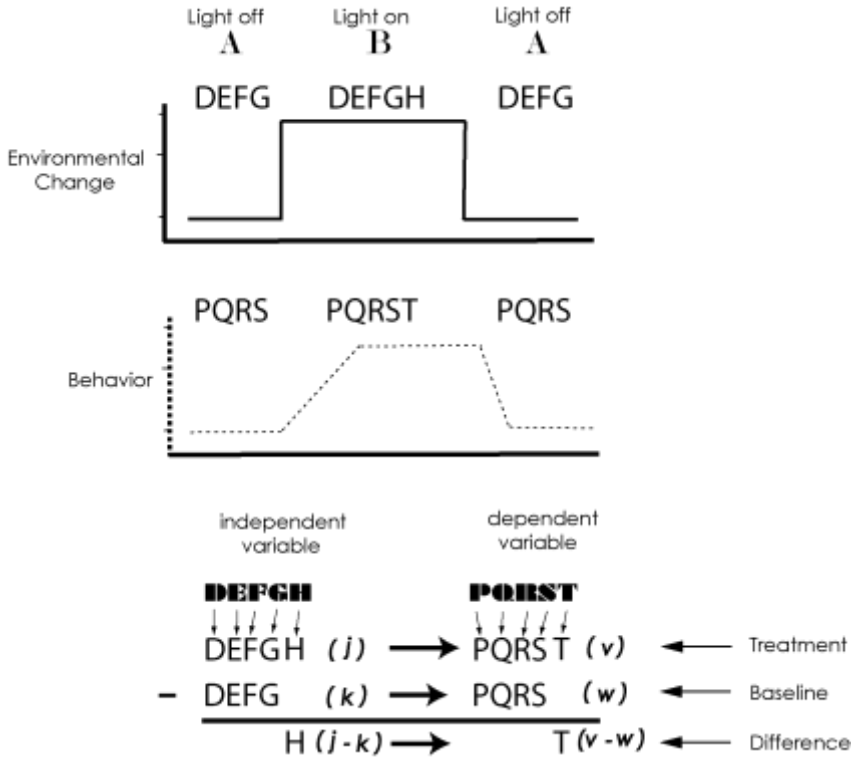


Figure 8.3 An explanation conceptualized as a cause-effect statement. The upper frame depicts the change in an independent variable. The second frame depicts the change in the dependent variable. The third frame depicts the independent variable and the dependent variable and depicts the difference in what was done (DEFGH – DEFG or ***j - k****) and the difference in what happened PQRST - PQRS or (****v - w****) along with the fundamental processes or laws governing each element* ***DEFGH*** *and* ***PQRST****.*

The bottom frame of Figure 8.3 is the semi-algebraic depiction of the above frames. The conditions in the treatment phase (summarized by j) and the resulting behaviors (summarized by v) are displayed across the upper horizontal line labeled "treatment." The horizontal line labeled "baseline" indicates the conditions (summarized by k) and the obtained behaviors (summarized by w) in the baseline condition when the light was off. In order to find any behavior change in the treatment condition we can subtract the baseline behavior from the treatment behavior (v-w). In order to determine how the treatment differed from the baseline, we can subtract the baseline conditions from the treatment conditions (j-k). This difference is displayed in the horizontal line labeled "difference" in the lower portion of Figure 8.3. A behavior difference of T (a peck) and a conditions difference of H (light on) are shown. It is therefore reasonable to conclude that H (light on) [or chance] causes T (pecking green light). The additional details depicted in the frame as emboldened letters will be discussed below.

3. Determining More Complex Cause Via More Complex Method of Difference

It must be reiterated at this point that explanations can vary in terms of their levels of molarity or their time scale. Depending on the specific research question, the simple question "why did the pigeon peck the green key" could be explained by a wide variety of molarity and time scales. Examples could include: 1) because the brain activated the muscle (cellular adaptation); 2) because the pigeons that did, had reproductive success, (long time scale organismic adaptation); 3) because the pigeon had been reinforced for that behavior in the past (short time scale organismic adaptation); or 4) because the key turned green (immediate time scale organismic adaptation. If our specific research question were, short time scale adaptation, we would give peck training as the treatment and would use extinction to recover baseline. We would find responding during the reinforcement contingency and none after extinction.

Additionally, explanation could be more or less comprehensive. Possibly the simplest being the key turned green, while the most comprehensive would begin with the big bang and end with the theory of everything. If our specific research question were quite comprehensive; we would provide control conditions that removed all but some chemical activity, others that removed all but some nerve tracks, others that removed all but some experience. We would also vary the time scale of some the treatment; for example, by providing control conditions that implement specific reproductive success, schedules of reinforcement or specific stimulus properties.

Finally, causation and its subsequent explanation could be narrowed to a very fine point. For example, the effect of gender, age, language accent, and hair style on the effectiveness of advertising could be assessed by setting up method of difference procedures where the only difference between tests were the issues of interest.

In each case, the procedure or the difference in what was done reveals the effect of that difference and <u>only the difference</u> on the obtained

dependent measure in terms of causation. In the example portrayed in Figure 8.3, in order to simplify the discussion of causation we are only interested in the immediate time scale adaptation. We don't care why the bird pecked green in terms of short, medium or long time scale organismic adaptation, nor why the bird pecked in terms of cellular or atomic adaptation.
The method of difference enables even the most punctilious usage of "A" **caused** "B" by permitting the cancelation of any unwanted potential cause whatsoever leaving only the causal factor under examination (or chance).

B. Focus on Proof of Causation, Multiple Converging Support, Generalization, and Prediction of Functional Relationships

In addition to the isolation of a causal factor, a "complete" explanation requires the characterization of all the elements and processes involved, and the specification of how elements or processes are related, so that the cause effect relationship can be seen as one of a larger set of possible functional relationships in a wide variety of situations. This data provides: 1) multiple converging evidence that the result is consistent with a wide variety of other functional relationships, 2) the information necessary to generalize the functional relationship to other situations, and 3) the ability to make principled predictions. The verification of those predictions validates the explanation. The falsification of the predictions allows the explanatory system to be corrected.

How information about a specific functional relationship can be generalized can be illustrated with the emboldened letters above the treatment line in the lower frame of Figure 8.3. These letters represent the characteristics and processes pertaining to each element in the procedure and results, and therefore how those elements and processes are related to similar elements and processes. It is in fact the information that defines the meaning of the term similar. It is this information that allows a functional relationship to be generalized to new situations that differs in various ways from the original finding and for predictions to be made about what would happen in a changed situation. Aristotle's way of conceptualizing the fact that learning to peck a key illuminated green was likely to also cause pecks to similar things was that the two situations were exemplars of the same formal cause.

A concrete instance of this is factor D which in the example represents the pigeon being at 80% weight. The emboldened **D** indicates that D is only one member of a family of body weights or motivational levels which could have various effects on the functional relationship if changed. This is the dimension across which a functional relationship can be generalized to different percent body weights, different motivational levels, and types of motivation in general.

An alternate way of describing the information depicted by the emboldened letters (e.g., **D**) is that they represent the covariance between the entity represented by its regular instantiation (e.g., D) and each of all other entities in the universe. For example, a green light going on has covariance (what is colloquially labeled similarity) with a yellow light going on and a bit less with a blue light going on and even less yet with a tone going on and very little with a

feather falling from the sky and probably none with Mount Everest eroding to a plain (except to some geologist).

Knowledge of the covariance with various other entities enables the better prediction of what behavior will occur when the pigeon is exposed to each novel stimulus, or experiences each alternative procedure or when alternate behaviors are used as the dependent variable. It is the meaning of understanding the laws of behavior, and the paradigm pertaining to organismic adaptation, or the formal cause to Aristotle.

It should be apparent that understanding something about the environment and behavior is necessary to generalize a functional relationship. It would be exceedingly difficult to generalize a functional relationship into a completely novel universe where everything in that universe was totally unrelated to any characteristic and process in this universe.

The following provides a sense of the information depicted by the emboldened letters and their bearing on generality and prediction with respect to factors other than the causal factor in isolation. The emboldened **D** represents the characteristics and processes related to being at 80% bodyweight, and how changes in body weight or changes in type of "motivation" are related to other motivational variables. The emboldened **H** represents characteristics and processes related to the light going on such as the effectiveness of any stimulus onset or the effectiveness of visual stimuli in pigeons. The emboldened **P** represents the characteristics and processes related to breathing and how breathing behavior is related to pecking novel salient stimuli. The emboldened **T** represents the characteristics and processes of the key peck caused by the light going on. More information than its simple physical characteristics is included, for example, how is that reaction to the light going on to be generalized to other situations. Essential factors would include was the behavior established by Pavlovian, Thorndikian, or evolutionary procedures, etc.

The result or difference in observed behaviors (v-w) or "T" or the key peck along with its paradigmatic context and classes or processes **T** is to be most correctly understood by relating it to its cause (j-k) or "H" or the green light going on along with its paradigmatic context and classes or processes, **H**.

The difference in the procedures separates the actual cause and explanatory context (i.e., "H" and **H**) from other possible causes (DEFG) and explanatory contexts **(DEFG)** by subtracting all the events and processes that don't result in a green light and key peck from all the events that pertain to the green light and the key peck occurring. In some cases of an explanation, only the causal factor is at issue. This could be seen as finding the necessary and sufficient causes along with the classes or processes these elements belong to, to whatever breadth and depth the question requires. In the present case of an explanation, H simply was the light going on. In other cases of explanation, the other elements of the experiment are at issue in order to provide for generality or prediction.

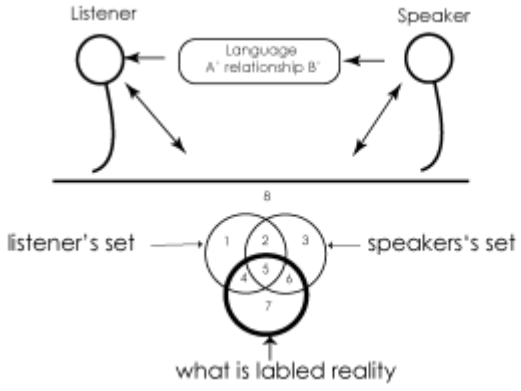
That is to say the focus of an explanation is typically on describing the class of manipulations and laws that produced the result and why it has that

inevitable result. In other situations, the information necessary to generalize or predict are the purpose.

An explanatory statement and the results of an experiment are inverse perspectives of the same relationships in nature. In an experiment, the cause is manipulated to discover the result. The key is turned green to see what happens. An experiment carries out the operations to the left of the yields arrow in Figure 8.3 and discovers the results to the right of the yields arrow. In an explanation, the purpose is the inverse issue which points out that the difference in the behaviors to the right of the yields arrow is explained by the difference in the procedures and their processes to the left of the yields arrow.

C. Focus on Sources and Types of Errors in Explanations

Figure 8.4 re-presents Figure 7.15. This figure characterizes error in a communication between a listener and a speaker. The dark circle in the Venn diagram represents what is taken as reality while the other two circles represent the speaker's set and the listener's set.



what is labled reality	4,5,6,7
speaker's elements	2,3,5,6
listener's elements	1,2,4,5

speaker's decisions	correct detection	5,6
	correct rejection	8
	false alarm	2,3
	miss	4,7

		wrt speaker	wrt reality
listener's decisions	correct detection	2,5	4,5
	correct rejecction	7,8	8,3
	false alarm	1,4	1,2
	miss	3,6	6,7

Figure 8.4 An illustration of the overlap, misses, and false alarms in a typical communication. The speaker's set can imperfectly capture the referent, and the listener's set with respect to the referent can be slightly different than the speaker's set. The circle drawn with a heavy line represents the set of elements labeled reality. The upper right circle represents the elements in the speaker's set. The upper left circle represents the elements in the listener's set. The various subsections of the circles making up each set are provided in the upper block of text. The second block of text provides the segments making up the various decision outcomes for the speaker's set. The lower block of text provides the circle segments for the outcomes of the listener's decisions with respect to (wrt) the speaker's decisions and with respect to reality.

Figure 8.5 depicts the error in a communication when that communication Is an explanation. These characteristics were directly or indirectly presented in the discussions of the two previous ways of conceptualizing an explanation or a communication and for the most part could be seen as little more than a rearrangement of the previously discussed issues into a different graphic. The issues are reiterated in the following paragraphs in terminology more typically applied to explanations, in order to connect to the vocabulary typical of discussions pertaining to explanations.

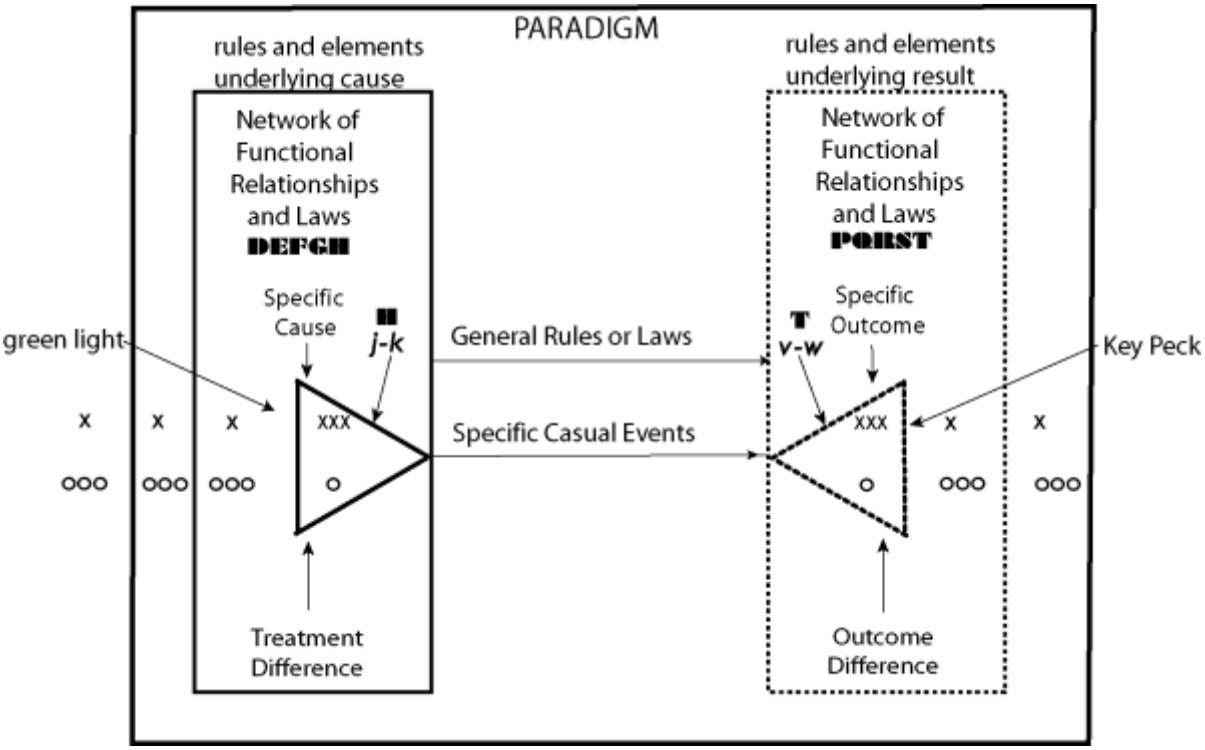


Figure 8.5 A depiction of an explanation in terms of its elements. Within a paradigmatic framework (the outer box), there are general functional relationships associated with the cause (left rectangle) and the effect (right rectangle). The left inner triangle is the specific causal factors (i.e., j-k), while the right inner triangle is the specific results factors (i.e., v-w). The x's and o's associated with each level of the figure represent misses and false alarms. See Figure 8.6 for details.

Figure 8.5 presents the general "scientific" paradigm with the outer box. This outer box represents the set of rules within which everything in science is seen. For example, ghosts simply do not exist, and all things are presumed to have a cause. The rules of science were discussed extensively in Chapters 1 and 2.

The left inner box in Figure 8.5 represents the paradigmatic and process context subset applicable to the explanation at hand. For example, the explanation for the key peck following the onset of the green light. It is the entire network of elements, events, processes, formal causes, and functional relationships or "laws" that at least roughly pertain to the cause of the behavior of interest (a key peck to a green light). They are a very broad range of material

and formal causes including such things as the experimental chamber, evolution, the functional properties of reinforcement, etc. They are instantiated as DEFGH for actual events or material causes, and **DEFGH** for respective classes of characteristics, processes, laws, or formal causes in Figure 8.3. They are instantiated as the lines selected to be emboldened to the left of the flower in Figure 8.1 from the nearly infinite number of elements and functional relationships that exist.

The right inner box of Figure 8.5 represents the network of output events, data, formal causes, and functional relationships or laws that roughly pertain to the resulting behavior of interest (a key peck to a green light) and its follow-ons. These are all of the various behaviors and laws that could occur given possible variations in the causal factors in the left box. They are instantiated as PQRST and **PQRST** in Figure 8.3. They are instantiated as the lines selected to be emboldened to the right of the key peck (the **+**) in Figure 8.1.

The left triangle in Figure 8.5 represents all the actual specific causal events of the situation of interest. It is more precisely captured by H in Figure 8.3. These are the class of necessary elements and the instance of the class of sufficient causes that was specifically involved in the event to be explained e.g., the illumination of the green light. The triangle on the right side of the figure is the specific output of interest and all of its fundamental processes or the key peck. It is given as T in Figure 8.3.

To review, the outer box is the paradigm (e.g., science). The left inner box is all the events and laws of nature that could pertain to explaining the green light. The left triangle is all the specific events and processes eventuating in a key peck. The right inner box is all the events and natural laws pertaining to the key peck, and the right triangle is the specific outcomes to be explained (e.g., the key peck).

1. Detailing Correct Detections, Correct Rejections, False Alarms, and Misses in Explanations

Figures 8.4 and 8.5 provides an opportunity to conveniently and clearly illustrate that all explanations, theories, and models have correct detections, correct rejections, false alarms and misses at each level of conceptualization. Figure 8.5 provides a space (in this case squares and a triangle) like a Venn diagram to position the Xs and Os to represent each possible decision outcome. A set that exists but that is not within the scientific paradigm, a set that is within the scientific paradigm but that is not in the general network of relevant factors, a set that is not a specific factor in the explanation, but is in the general network of relevant factors, and finally the specific factor of interest.

The Xs in Figure 8.5 represent events and laws that truly pertain to the outcome and its explanation and are either correct detections or are misses, while the Os represent events and laws that are truly irrelevant to the outcome and its explanation and are either correct rejections or are false alarms.

Xs and Os outside the outer paradigm box are considered invalid by the rules of the paradigm. The Os are truly outside the paradigm while the Xs have been incorrectly rejected by the paradigm. The Xs and Os outside the inner boxes but

inside the large outer box are functional relationships or laws that are considered totally irrelevant to the cause (left box) or effect (right box). These are correct decisions for the Os but are incorrect for the Xs. The Xs and Os inside the inner pertinent functional relationships box but outside the triangles are considered related but not to the specific cause or effect, and finally those Xs and Os within the specific cause or specific effect triangle are events and processes thought to directly pertain to the explanation of our specific cause or effect; correctly [Xs] or incorrectly [Os].

IV. Evaluation of Explanations, Theories, and Models

Even though all the items in the following list (A through J) apply to explanation, theories and models, those that concern prediction most obviously (but not exclusively) apply to theories and models.

In order to simplify the exposition of the commonalities of explanations, theories, and models, the terms elements, processes, and data will be used. In the case of explanation, most typically the data come first and the elements and processes are offered. In the case of theories and models, most typically the elements and processes come first with the data being subsequently generated to use or to test the theory or model.

While reading the following material, be sure to look at Figures 8.3, 8.4 and 8.5 for the referents. The text would be unmanageably long or conceptually challenging without some visual representation.

A. Unequivocally Deterministic

Any explanation, theory, or model must be unambiguously deterministic. It must be formally accepted that whatever behavior happened had a cause. While the exact details of the causal factor need not be presently known, the explanation, theory, or model must be considered tentative until the necessary externalistic conditions that reliably “turn on” and “turn off” the effect have been demonstrated. Recall the example of the single neuron organism and the egg retrieving gull given in the preface.

When the cause for an effect is not known then the identification of the cause is of major importance. There must be a factor (e.g., “H in Figure 8.3) which produces the effect (e.g., T in Figure 8.3) in the fashion "if H then T". Additionally, There must be plausible converging evidence that the predicted output would reliably occur given that manipulation of the antecedent events.

A second issue when establishing a causal factor is the demonstration that the externalistic causal processes has been correctly identified and characterized. This is accomplished by way of demonstrating the similarity of the effect with other comparable manipulations in comparable situations. Good explanations, theories, and models invoke processes shown to work in a wide enough variety of

situations to demonstrate the plausibility of that process in the situation for which it was invoked. The factors causing an effect are not simply an eternal place holder or free parameter that awaits eventual clarification at some later date. Neither are the causal processes inferred internalisms. Failure to establish converging empirical support for the causal process in a timely fashion discredits the validity of the explanation.

An example of a failure to establish reasonable causality is equine therapy. Some proponents of equine therapy believe that putting PTSD patients around horses fixes those people. These beliefs are not based on any experimental evidence that being around horses fixes people. It is a simple matter to give one third of the patients a horse, one third a dog, and one third a human friend. If the group given a horse were clearly better off, then a causal effect of horses would be demonstrated. Additionally, a plausible means for the effect is not offered for how equine therapy accomplishes its effect. The effect could be caused by a gas given off by horses, humans taking the horses as a model of how to behave, or the PTSD behavior being extinguished because the horses don't react to it, each of which could be experimentally evaluated. Unfortunately, the proponents of equine therapy feel no burden to prove equine therapy works, nor to even provide evidence how it could work. It's not as if it is inconceivable that equine therapy could work, but as it is, its a totally unfounded superstition.

B. Understood Facts and Processes

To be useful, an explanation, theory, or model must enable its practitioners to describe, predict, control, synthesize, and explain phenomena. Additionally, it must be presented in such a way that as many people as possible could use the information. This latter goal is even more essential as a science matures and becomes more recondite. Even under ideal conditions, fewer and fewer participants have the capacity to use the most complex knowledge of a field. For example, it is said that fewer than a dozen people truly understand (or actually see the dolphin) in Einsteinian physics.

With respect to the behavior analytic paradigm; analogies, metaphors and folklore have an problematic relationship with "understanding". Some of the predictions of analogies, metaphors, and folklore are correct and some of the internal machinery of those explanations comfortably lead to the predictions. However, behavior analysis is exclusively focused on: 1) external functional relationships, everything else is irrelevant and meaningless and, 2) the overt consideration of the miss and false alarm rate of explanations, systems that produce ambiguous predictions and explanations are seen as inadmissible. The requirement is identifying true predictions from false ones before the fact and avoiding the trap of believing the internal process on the occasions when the prediction turns out to be true.

1. Analogies or Metaphors Versus Understood Factual Elements and Processes

Analogic or metaphorical elements and processes can be advanced as an explanation, theory or model based on either nothing more than a rough resemblance to their target or the confusion of a synonym or tautology being taken as an explanation. Analogies and metaphors are not necessarily false, but neither are they necessarily true just because they may have some functional properties that are similar to their target, or sound informative.

First, analogies or metaphors can have a very alluring "syntax", however, it is essential to keep in mind that analogies and metaphors do not have a correct or necessary connection to nature or the essential "semantics". For example, early explanations of conception were that the father planted his "seed" in the fertile soil of the mother to produce a baby. This explanation was false. A similar effect such as planting a seed and conception may not have similar causes.

Secondly, analogies and metaphors often tell us nothing more than we already knew. Freud's often-repeated mechanism for mental activity was "pressure builds up in the id until it breaks through and causes such and such behavior." When people say they are Freudian, more than likely what they actually believe is that if pressure builds up enough in a closed system then something will burst, thus "relieving" the pressure. Unfortunately, they are so caught up in the intuitively obvious validity of the physics of a hydraulic mechanism that they don't realize they are confusing a tautology or synonym with an explanation.

At the end of the day, it is the quality of predictions and the ability to generalize the predictions that an explanation, theory, or model makes that defines how well nature is understood not its intuitive appeal.

2. Folklore Versus Understood Factual Elements and Processes

Often, notions creep into "common knowledge" through a back door without passing any test to assure that they are actually true and understood processes. A surprisingly common pathway is that offhand, unproven conjectures presented in discussion sections of research papers are repeatedly invoked as if they were the point proven by the procedure even when they were not. Soon it becomes "common knowledge" that a particular paper proved something that in fact was only a speculation.

The widespread belief that only a single response would occur in an explicitly timed fixed interval schedule advanced by Ferster and Skinner would be an example of a belief based in folklore rather than being factual proven knowledge. No research had been done on the procedures before it was offered. Ferster and Skinner's speculation has now been proven wrong. Simply put, an explanation, theory, or model may be only folklore rather than meaningful knowledge and therefore may not actually provide for understanding the phenomenon it purports to explain.

C. Integration Within the Behavior Analytic and Scientific Paradigmatic Context

Behavior analytic explanations, theories, and models and their data must be integrated within the scientific paradigm (outer and inner boxes in Figure 8.4) and as discussed throughout this entire text.

D. Externalistic

While an intrinsic aspect of the behavior analytic paradigm is its exclusive focus on external events. It's beneficial to explicitly recognize that essential characteristic at this point.

E. Nontautological

No aspect of an explanation, theory, or model can be tautological. The boundaries of **j** - **k** (the "cause") and **v** - **w** (the "effect") (illustrated in Figures 8.3 and 8.5) must be different. If there is no independent evidence for both the cause and effect, then they are the same thing. The cause cannot be a restatement of the effect, such as "the paper is burning because it is burning" or its more typical instantiation "the paper is burning because it caught fire." If the cause is simply a restatement of the effect, you are not dealing with a functional relationship (an input and output, or a cause and effect). Rather you are simply talking about an effect (burning) and then using a synonym for that effect (catching fire) as the cause. Explanations for behaviors must add to our knowledge or understanding, not simply clone the words. If you were to pay $100.00 to consult a dictionary or an expert with the following question: "What does the principle of 'scientific manipulation' mean," and they responded: "that's when you manipulate things scientifically," then you would not be happy because you would not have gained much new information or understanding for your money. To reiterate, when a functional relationship between two elements is proposed, both elements must be unambiguously and independently connected to separate empirical events. Three tautologies that are frequently in people's verbal repertoire are: that person thinks other people are trying to hurt them because they are paranoid, gravity caused the object to fall, and reinforcement caused the rate to increase.

It would be productive at some point to 1) write down a few behaviors in a column. For example, a goose retrieves an egg, the person laughed, the baby cried. 2) To the right of each behavior, write nothing more than a synonym for the behavior. Alternatively, make up a thing in the brain with the same name as each item in the first column, as such. Johnny is crying because the crying center of the brain was activated. 3) Now go to someone and say you learned what causes the behaviors in the left column by reading out loud what you wrote in the right column. 4) See what they say.

Note that the task of the game is not to simply provide people with wrong information. Rather, it is to tell them nothing more than the effect relabeled as a cause. Such as laughter comes from the laughter part of the brain. The task of the

above game is to seemingly explain with a tautology: George is standing where George is standing; the yellow thing is yellow; I am happy because I am happy. Science requires something better.

F. Functional Properties

There must be a clear specification of how the general class of results to be explained is expected to change as a function of classes of manipulations. Much as images and options on the screen of your phone change as a function of things you do with your hand on the screen. The wider the range of classes of manipulations that are understood and the wider the range of procedures within classes, then the better the explanation, theory, or model. The steadfast reliance on functional analysis and functional definitions is a hallmark of behavior analysis.

G. Explicit / Unambiguous

An explanation, theory, or model and its data must be explicit. The boundaries of **j**, **k**, **v**, and **w** in Figures 8.3 and 8.5 must have only one interpretation. In order to properly explain or predict a phenomenon, the communication must explicitly and unambiguously specify the proposed functional relationships, mechanisms, and data rather than vaguely allude to something that might be something else. A good example of providing an explicit unambiguous definition of something is the chain in a football game being used to determine a first down.

A second type of ambiguity is with respect to when the explanation, theory, or model is to be invoked. Clearly only invoking the explanation when it works doesn't reflect its actual value. If you apply the explanation to the 10% of the situations where it works you can hardly claim it works 100% of the time it was tested. After all, the point of all explanation, theories, and models is to communicate knowledge, advance our knowledge, and to detect and correct any errors in our understanding. Fumbling around because of ambiguity serves none of those purposes.

The point of a principled system is to have a system which preserves those aspects of our knowledge base which are correct and which corrects any aspects which are wrong. Ambiguity makes this impossible because the explanation, theory, or model may be right or may be wrong, it may apply or it may not depending on which alternative is used. Given that ambiguity, no progress is possible.

H. Minimal Error

The issue of error is fundamental to explanation theories and models. It was also covered in the original presentation of conceptualizations of an explanation. In the present case, the issues are more formally covered.

The upper portion of Figure 8.6 presents the decision dimension of explanations, theories, and models in terms of a contingency table. Explanations, theories, and models and their predicted data, like any other decisions, each have four possible occurrences: correct detections, false alarms, misses, and correct

rejections. This issue was covered earlier in Figures 8.4 and 8.5.

The lower portion of Figure 8.6 depicts a decision analysis of the elements of an explanation, theory, or model as the left oval while the right oval provides a decision analysis of the predictions of a model or theory. Each has four possible outcomes associated with it. These are noted in the figure and are enumerated in text in the section below the figure. The numbers in parentheses within the figure indicate the applicable verbal description given in text below the figure.

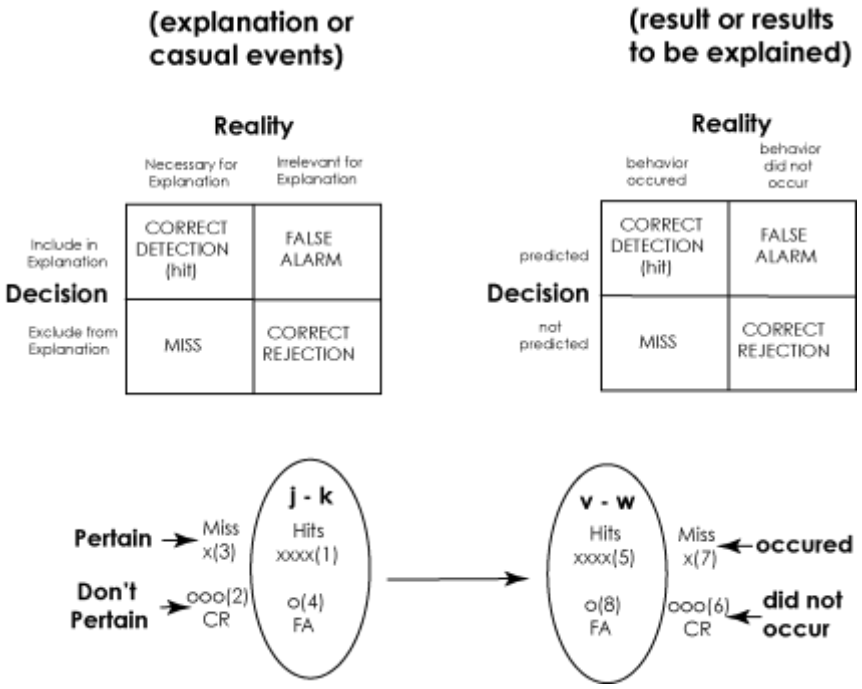


Figure 8.6 A decision analysis conceptualization of an explanation, theory, or model. The upper section provides the decision analysis contingency table while the lower section provides a set diagram illustration of the causal events and results to be explained with decision analysis labels.

Please consult the lower portion of Figure 8.6 and look at the numbers in the figure corresponding to numbers given in the following list.

Re: The two correct factors in the explanation, theory, or model (i.e., left oval)

1. Elements that should be included are included in the explanation, theory, or model. (x's contained within the oval set): Correct Detections or Hits
2. Elements that should not be included are excluded from the explanation, theory, or model (o's excluded from set): Correct Rejections

Re: The two types of errors in the explanation, theory, or model (i.e., left oval).

3. Elements that should be included which are not included in the explanation, theory, or model (x's left out of the set): Misses. By their nature, this type of error cannot be known until a theory, model, or explanation fails to explain or predict something. When that occurs, the error is labeled "lacking generality."
4. Elements that should not be included which are included in the explanation, theory, or model (o's included within set): False Alarms. This

error is labeled "being unparsimonious" because the theory has some element it does not need (see below).

Similarly, a decision analysis can be applied to the results to be predicted (the data) (right oval).

Re: The two ways for the predictions of a model or theory to be correct

5. Results that were predicted to occur occurred (x's contained within the set) (correct detections or hits)
6. Results that were predicted not to occur, did not occur (o's excluded from the set) (correct rejections)

Re: The two types of errors in predicting results

7. The results that were predicted not to occur, that did occur (x's excluded from the set that should have been included (misses)
8. Results that were predicted to occur that did not occur (o's included in the set that should have been excluded (false alarms)

Science is the process of developing more correct or more perfect boundaries for the two sets illustrated in the lower portion of Figure 8.6. In other words, fewer false alarms and misses and more correct detections and correct rejections in both the explanation, theory, or model and the data being explained or predicted.

1. Parsimony in Explanations, Theories, and Models

The boundaries of **j** - **k** (the predictor or causal explanation) must be defined in such a way as to minimize as many elements which do not belong as possible (i.e., false alarms or (4) in Figure 8.6.

An example which illustrates a successive loss of parsimony is provided in the sequence of increasing complex descriptions for the same event (a key peck occurred, the pigeon learned to peck the key, the pigeon learned to peck the key in order to get food, the pigeon knew it had to peck the key in order to solve its need for food, etc.).

Simplicity does not prove that an explanation, theory, or model is correct, but simplicity is preferred over complexity.

2. Generality in Explanations, Theories, and Models

Explanations, theories, and models must be general or comprehensive. The diversity of situations to which a theory or model can be applied importantly determines the usefulness of that explanation, theory, or model. A theory, model, or explanation must minimize misses in predictions (illustrated by 7 in Figure 8.6. In sum, the more phenomena covered and the wider the range, the better the explanation, theory, or model. The principle of reinforcement is one of the most general principles of psychology.

3. Conceptual Follow-Up: Optimal Tradeoff

There are two types of errors that the explanation, theory, or model can make (left side of Figure 8.6), and two types of errors pertaining to the results or data (right side of Figure 8.6). Clearly, having no errors on either side is best. But given that there will be errors, science attempts to optimize its net impact. The idea is to explain or predict the maximum number of phenomena (minimize unexplained results [7]) while minimizing the number of rules necessary to accomplish that end (minimize needless causal events [4]). (Note that parsimony is the term for minimizing needless causal events [4] without considering the cost in terms of other types of error. Generality is the term for minimizing unexplained results (7) without considering the cost in terms of other types of error.)

This could be seen as trying to explain more data with less theory. All other things equal, a false alarm or the inclusion of an unnecessary theoretical element on the rule side (4) is considered worse than having a necessary one missing (3). Secondly, it is considered worse to have a restricted range of applicability (7) on the data side, than explaining something incorrectly (8).

4. Quality of Prediction

a. Validity of Explanations, Theories, and Models

The degree to which the average of several predictions of the theory, model, or explanation match the average of the target behavior is important. This is often worded as, "are you measuring what you think you are measuring?" Using a bulls-eye metaphor, it is the degree to which the arrows average in the center of the target even if they are spread out.

b. Reliability of Explanations, Theories, and Models

The degree to which the theory, model, or explanation's various predictions of the same event are similar to each other is an important indication that the model does not make random predictions. This is often worded as, "are you getting the same value over and over?" Using a bulls-eye metaphor, it is the degree to which the arrows land very close to each other even if they are off center.

c. Percent Variance Accounted For of Explanations, Theories, and Models

The greater the percent of the variance accounted for, the more meaningful and useful the explanation, theory, or model. For example, if measures of behavior vary from 0 to 100 (e.g., test scores) that would be the amount of variance in the original behavior. Let's presume that with the help of the explanation, theory, or model, the original data can be separated into categories (for example, children in first, second, third, and fourth grade) if partitioned that way then it would result in the test scores falling into categories of 0-24, 25-49, 50-74, and 75-100, then a substantial portion of the variance in the original data (scores from 0 to 100) has been accounted for because the variance is now only 25 points. If the elements and

processes only enabled a reduction of variability from 0-49 and 50-100 (for example, children younger or older than 8 years old), then that theory is not as good because there is less variance accounted for. We would say the best way to predict a child's test scores is with their grade level not their age.

d. Minimal Free Parameters

Explanations, theories, or models that explain or make predictions with fewer free parameters typically are to be preferred over those with more, free parameters. Free parameters are "fudge factors" or wild cards built into the explanation, theory, or model. For example, you can "predict" the number someone will make up by saying it is the number 37 times a free parameter. When they say the number if 14,651,922 then you divide 37 into 14,651,922 and use the answer as your free parameter. Simply multiply 37 times the free parameter and you get 14,651,922. This free parameter procedure will "predict" any possible number anyone could possibly make up. To people who don't understand the flaw in using free parameters, the "theory" will be 100% correct. The quip for the false sense of accomplishment resulting from the use of free parameters is "with two free parameters, I can draw an elephant, with three, I can make its ears flap." The point being there is not much glory in using a free parameter to make. your prediction work.

e. Elemental Prediction and Emendations

The fewer emendations an explanation, theory, or model requires to make a correct explanation or prediction, the better. Additional processes or emendations can be invoked after the fact, to whatever extent is necessary to explain or to have "predicted" any obtained results. Emendations could be seen as non-numerical free parameters. The quip for the false sense of accomplishment provided by this type of post hoc correction is "a square cake can appear to be round with enough frosting." The point being the more emendations necessary, the less glory.

I. Principled / Testable

Additionally, predictions must be principled which is to say that the theory, model, or explanation must: 1) arrive at the same prediction regardless of who is using the theory (the theory must have predictions that are principled rather bring someone's intuition) and, 2) the theory must necessarily be changed if the predictions are falsified.

An explanation, theory, or model must be testable. For example, the boundaries of **j**, **k**, **v**, and **w** in Figure 8.3 must allow someone to correctly predict whether an elements of the procedure and results are within or not within the theory rather than being corrected based on the obtained results.

1. Confirmable

At least one element must be able to be predicted by the rules of an explanation, theory, or model and obtainable as the result of empirical confirmation. Note that it may be an observation, which has never been made, or one that cannot currently be performed. Einstein's theory of relativity predicted that light would be bent when passing close to large masses. That prediction was confirmed 50 years after it was made when astronomers demonstrated that light from a distant star was bent when it passed by a star.

2. Falsifiable / Risky Prediction / Information Transmitted

A second "testability" criterion for an explanation, theory, or model is known as falsifiability or making a risky prediction. A useful theory must tell you something more than what is guaranteed by the situation itself. The explanation must contribute to your knowledge or ability to solve problems or it has no value. If a theory or prediction is true, it cannot be true only by twisting the meaning of true.

If I tell you that a coin toss will result in a "head or a tail" then I haven't told you anything that was not inevitable in the situation and that you didn't already know. Even though future events will prove one aspect of the predictions (a head or a tail) could be labeled "true," the other half of the prediction (a tail or a head) was wrong.

The falsifiability requirement can be made more intuitive by using the notion of transmitted information. The information transmitted (or the degree of knowledge conveyed) in a communication is the amount of uncertainty reduced. Note the following figure. If you had to guess the value of a number between 1 and 10, and the answer was "6" and I told you that it was the number 6 (see line B), then I would have reduced your uncertainty to zero.

	<- - - Range of Uncertainty - - ->									
A	1	2	3	4	5	6	7	8	9	10
	Communication									
B	x	x	x	x	x	6	x	x	x	x
C	x	x	x	4	5	6	7	8	x	x
D	1	2	3	4	5	6	7	8	9	10

Figure 8.7 A depiction of the information transmitted in three communications. Communication "B" is the correct answer. Communication "C" excludes some possibilities but also includes erroneous alternatives. Communication "D" provides every possibility, and therefore is useless.

I would have also told you something (albeit less) if I told you that the number was between 4 and 8 (see line C). I would have reduced your uncertainty by half. However, I would not have told you anything at all if I told you the number was between one and ten (line D). Your uncertainty would not have been reduced at all. That was the entire range of the possibilities guaranteed by the situation

itself. It was inevitable that the unknown number would be between 1 and 10. But, in this last example (that the number is between 1 and 10), it is also the case that one of the numbers I told you would necessarily have been correct. I could not have been proven wrong no matter what the correct answer was. This impossibility of "error" explains why these seemingly correct, but uninformative utterances (the answer is between 1 and 10), are used so often by unscrupulous people.

Philosophically, these uninformative theories are said to make no "risky predictions." They cannot be disproved (in the sense of having said something that was wrong when it was actually right) because they predict everything. Science demands that a theory make a risky prediction or be falsifiable, because you cannot be right (i.e., communicate information) if you cannot be wrong (i.e., some conceivable outcome would prove you wrong). Science is interested in the size of the x'd in area in Figure 8.7. Theories that make predictions that produce big x-ed-in areas (much information transmitted) are good theories, those which produce less x'd in areas (less information transmitted) are less acceptable. The task is to minimize false alarms in predicted data or "8" in Figure 8.6. Let's face it, advisors are not much good if they agree with everything you say. They give you no more new information than a tape recording of your own voice.

3. Conceptual Follow Up: Repercussion of Falsification

Correcting a falsified principle is obligatory in a principled explanatory system. The explanatory system is simply gibberish and cannot possibly be correct if it has an outstanding falsification. The flaw in the theory must be corrected or the falsification must be refuted - there is no middle ground.

J. Productive

An explanation, theory, or model is not very valuable if it cannot be used in some way to either make useful predictions or help advance our conceptualization of the causes of behavior.

Explanations, theories, and models cannot be little more than what, in effect, are tautologies but rather must connect to prediction, control, and synthesis of the phenomena and must provide a way to comprehend or predict a meaningful amount of the variance in nature.

V. Conceptual Follow-Up: Terms Pertaining to Explanations

Observations are the description and documentation of objective events in nature. Multiple observers must "see" the same thing. The results of observations can reveal a correlation between events and therefore can result in knowledge (i. e., behavior under the control of covariance in nature).

Covariance is the systematic covariation in two sets of observations such that the variance of the predicted scores can be reduced (obtain a more accurate prediction) if the predictor scores are known because the variation of the individuals within each subgroup around the mean of that subgroup is less than the variation of all the scores around the mean of all the scores.

Experiments are procedures that can reveal a specific type of covariance labeled a cause-effect relationship.

Cause: a minimal set of empirical events that is sufficient to produce an effect. Recall that many components of a cause are taken for granted. For example, all known uses of the term cause presume the existence of the universe. Note that all criticisms of the term cause also apply to all of its euphemisms, such as "controlling factor."

Effect: a set of empirical events that occurred given its cause

Knowledge is the label for behavior under the control of covariance between empirical events.

Direct knowledge: Behaving with respect to covariance acquired as the result of direct exposure to the covariance.

Indirect knowledge: Behaving with respect to covariance acquired as the result of someone else's verbal behavior.

Inferred knowledge: Behaving with respect to covariance acquired as the result of inference from other experienced covariance.

Theories are the integrating/contextual verbal behaviors that provide the paradigmatic framework and functional properties as well as the metaphors/ analogies/intuitions that allow generalization or a prediction of behavior to be more easily, correctly, and appropriately invoked, implemented, and interpreted. For example, in the theoretical statement "reinforcement strengthens behavior." The term "strengthens" is only an analogy or metaphor but it provides a basis from which predictions about behavior can be made. For example, strengthened

behavior is less likely to be altered by something. The better the paradigmatic integration, the more broadly supported, and the more specific the predictions, the better the theory.

Model: A model is a formal system that makes explicit predictions of behavior given specific precursors. The more broadly applicable and the better the quality of generalization and prediction, the better the model. The difference between theory and model is a bit vague but theories tend to be more verbal while models are more equation-like.

Cause-effect model: The specification of the specific events expected to result in an effect. In that sense, it is the verbal instantiation of an experiment with its expected results.

Correlational model: The specification of an expected relationship between events. In that sense, it is the verbal description of a correlation.

Laws are the specification of invariant relationships in nature. They are obtained functional relationships that characterize a class of empirical relationships within their range of applicability and are relatively independent of a theoretical framework.

Predictions and **Explanations** are inverse processes and can be seen as rather like two sides of the same coin. Predictions proceed from theories/models to data while explanations typically proceed from data to theories/models.

Prediction is the specification of the behaviors that must occur given specific prior events based on the covariance articulated by a model or theory. In that sense, a prediction is the verbal instantiation of an experiment and its results before it is carried out if the prediction is a cause-effect prediction, or a relationship between observations before it is measured in the case of a prediction of a correlation.

Explanation shows how obtained events are the logical outcome of the covariance articulated by models and theories. In that sense, it is the verbal instantiation of a cause-effect relationship. The more complete the explanation, the more support for generalization and prediction from the explanation as well as the more validation provided by multiple converging evidence.

With respect to a functional relationship, an explanation:

1. **provides for its validity through multiple converging evidence**
2. **provides a paradigmatic context for the functional relationship**
3. **specifies the cause of the functional relationship**
4. **enables the generalization of the functional relationship**
5. **enables predictions of new functional relationships.**

CHAPTER 9

Nonbehavioral Explanatory Mechanisms

I. Nihilistic Approaches to the Cause of Behavior

II. Pseudo Explanation Via Confusion, Emotion, Empathy, or: "Rhetorical" Explanations

A. Francis Bacon's origins of erroneous reasoning
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   2. idols of the market place
   3. idols of the theater
   4. idols of the cave

B. Charles Peirce's rationales for erroneous reasoning
   1. tenacity (and novelty)
   2. authority (and antiestablishment)
   3. a priori (subjectivism)
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C. Classical forms of erroneous reasoning
   1. argumentum ad baculum
   2. argumentum ad hominem
   3. argumentum ad ignorantiam
   4. argumentum ad misericordiam
   5. argumentum ad populum
   6. argumentum ad verecundiam
   7. false cause (post hoc)
   8. complex question
   9. ignoratio elenchi
   10. petitio principii (tautology)
   11. equivocation
   12. amphiboly
   13. accent
   14. false equivalence

D. Lies
   1. adding information that is not factual (lie of commission)
   2. removing information that is of importance (lie of omission)

E. Conceptual follow-up: the invisible but substantial loss of critical thinking in the American culture

III. Pseudo Explanation Via Specification of Future Causation or: Teleological Explanations

A. With intentionality
B. Without intentionality

IV. Conceptual Precursor: Fundamentally Different Epistemological Approaches to Explain the Causes of Behavior

V. Explanation Via Appeal to Inner Cause, or: "Internal" Explanations

A. Types of internal entity
   1. empirical
   2. nonempirical
      a. with basis only in folklore (mentalism)
      b. with inferential support (cognitivism)
      c. conceptual follow-up: the difference between cognitive and mentalistic explanations

B. Flaws of internalism as an explanation of behavior
   1. internalisms are not necessarily resolvable/falsifiable
      a. unfalsifiable internalisms
   2. internalisms are not productive
   3. internalisms divert attention
   4. internalisms are irrelevant
   5. the justification or necessity of internalisms is arbitrary
   6. establishing the reliability of internalisms is problematic
   7. internal verbal activity as a cause of behavior is inconsistent with empirical findings
      a. internal verbal activity is nonempirical and tautological and is therefore, ineligible to be a cause of behavior
      b. internal verbal activity as a cause of behavior is inconsistent with evolution
      c. internal verbal activity as a cause of behavior has been invalidated by split brain research
   8. conscious realization or awareness as a cause of behavior is inconsistent with empirical findings
      a. conscious realizations controlling behavior has been invalidated by protracted extinction
      b. conscious realizations controlling behavior has been invalidated by self-destructive behavior
      c. learning occurs without conscious realization and therefore conscious realization cannot be a necessary cause of behavior

d. stimulus control occurs without conscious realization and therefore, conscious realization cannot be a necessary cause of behavior
e. extremely complex adaptive behavior occurs in decorticated animals
f. conscious realization as a cause of behavior is counterfactual

CHAPTER 9

Nonbehavioral Explanatory Mechanisms

Before embarking on the next two chapters, it is worthwhile to review the material we have covered so far to better integrate the conceptual foundations for these next two chapters. Initially, we demonstrated why it's important to be "scientific" (i.e., it is worth the effort). We then developed an overview of what science, and psychology in particular are and how they fit within all human endeavors. Next we saw that variance in the natural world is the problem we are trying to understand. Finally, we developed a comprehensive and detailed understanding of the products of science: knowledge and explanation.

These next two chapters lay out the fundamental, substantive, incommensurable, irreconcilable differences between non-behavioral and behavior analytic explanatory mechanisms.

I. Nihilistic Approaches to the Cause of Behavior

There are a variety of approaches to conceptualizing behavior. This text does not consider nihilistic views such as those that assert that behavior must be taken "as is" without analysis, or those which consider it impossible to explain behavior. Pseudo explanations built on God's will, space aliens, and free will are also dismissed out of hand.

II. Pseudo Explanation Via Confusion, Emotion, Empathy, or: "Rhetorical" Explanations

Rhetorical explanations are not really explanations at all and are therefore unacceptable even though they can be made to appear correct by fiction writers or our own confusion. They are non-empirical verbal statements chosen to produce agreement not explanation. For example, "we should not give these people fair trials because they savagely murdered people we all loved" (the reason causes empathy for the view but contributes nothing to knowing their guilt); "evolution

is false because humans are debased by a view which suggests that they evolved" (an invalid emotional argument that contributes nothing towards the disproof of the view); "things fall because of gravity" which basically states things fall because the name for things falling is "gravity" (a tautology). "They are guilty, the news report made it obvious" (confusing fiction and fact). These example "explanations" are actually nothing more than verbal confusion.

This is not to say that the position argued by rhetorical explanations is necessarily wrong. Rather the reason for the position is unacceptable. It may be a fact that the person is a terrorist. It is a belief based on an unacceptable premise however, if you believe they are a terrorist simply because they are a Muslim. It may be that a soldier is a noble war hero but it is a belief based on an unacceptable premise if it is based simply on the fact they are a member of Seal Team Six. In reality, they could be a war criminal. The examples provided for each of the following instances of rhetorical explanations are obvious errors so that the flaw in reasoning can be better illustrated. The challenge is to identify rhetorical (and therefore invalid) reasoning when that flaw is very subtle.

A. Francis Bacon's Origins of Erroneous Reasoning

Francis Bacon described four types of illusions or types of threats to critical thinking. They are not the best analysis of faulty reasoning but they are often cited in discussions of rhetorical explanations. His categories were based on how a person came to think incorrectly. Unfortunately, Bacon's conceptualizations have boundaries that do not correspond with modern conceptualizations of behavior. For example, he separated sources that we now know to be the same and he combined sources now thought to have separate causes. His types of erroneous reasoning or "idols" are therefore impossible to translate in a simple linear fashion, but we can roughly translate them. Recall that these beliefs are not necessarily wrong; rather the reason for the belief is unacceptable. It is not that lynched people are always innocent; rather, an action was taken for an unacceptable reason.

1. Idols of the Tribe

These are errors in reasoning attributable to the phylogenic and ontogenic experiences common to all humans, in lieu of logic, understanding, or explanation. Bacon labeled these "human nature." The implication was that these idols are an intrinsic part of what it is to be human but could be wrong. Examples of what Bacon intended by this category would be that most people have a great deal of difficulty understanding or accepting the functional relationships exhibited by quantum mechanics. At the quantum level, something can move from Point A to Point B without passing through any of the intervening space. Because humans have commerce only with levels of reality where things absolutely must pass through all intervening locations, quantum logic is very alien, seemingly ridiculous, and therefore obviously wrong to amateurs.

Serious errors occur when these misunderstandings, common to most humans,

are accepted as facts even though they are some odd mixture of facts and fiction. In Bacon's words, "Imaginings gain dignity and are mingled with facts." In simplistic terms, idols of the tribe are errors based on human nature or the experiences common to virtually all people.

2. Idols of the Market Place

These are errors in reasoning attributable to the nature of language, in lieu of logic, understanding, or explanation. In Bacon's words, "Words betray their own purposes by obscuring the very thoughts they are designed to express" (i.e., the word does not capture the full richness of the contingency that evokes it). The clearest example would be errors in thinking caused by the lack of a common operational definition for a term between two people discussing some issue. A specific example is the belief in mental causation because there is an English word for "the mind." Recall the number of sentences and paragraphs in virtually every section of this text whose sole purpose is to clarify the difference between common meanings of terms and the correct referent for those terms (e.g., truth, understanding, reality, knowledge, memory, etc.). In simplistic terms, idols of the market place are errors based on flaws in our language.

3. Idols of the Theater

These are errors in reasoning attributable to a false paradigm that was established in the person by deliberate indoctrination by some group in lieu of logic, understanding, or explanation. The false paradigm is typically established through trickery, sophistry, and deliberate deception even if its proponents believe their intent is honorable rather than self-serving and malicious. These sources include cultural tradition and religion. The easiest to understand examples of this type of error would be illustrated by the faulty reasoning of the people who believe religions other than your own, or the faulty reasoning of the people of a nation other than your own that invade their neighbors. In simplistic terms, idols of the theater are errors based on a faulty paradigm that we are tricked into believing.

4. Idols of the Cave

These are errors in reasoning attributable to an individual's idiosyncratic mindset, in lieu of logic, understanding, or explanation. Bacon labeled this "peculiar and singular disposition." A person tends to only know what their own personal paradigm "permits" and they could thereby be limited by their personal paradigm if it is incorrect. The label for this category is by analogy to Plato's shadows on a cave wall. People see in unclear situations what best fits their own personal expectations and they could thereby be wrong. An example would be a very selfish person might interpret everyone's motives as selfish. A person's idiosyncratic beliefs are the target of the notorious Rorschach test.

Bacon differentiates an individual's idiosyncratic paradigm that is acquired through incorrect reasoning, by accident, or from a variety of uncoordinated

sources (i.e., idols of the cave), from those that are inborn (i.e., idols of the tribe), as well as those that are deceptively and deliberately promulgated by a group (i.e., idols of the theater). In simplistic terms, idols of the cave are errors based on a faulty paradigm that we unsystematically acquire on our own.

B. Charles Peirce's Rationales for Erroneous Reasoning

A different list of rationales for faulty reasoning was offered by another scholar and is also often cited in discussions of erroneous reasoning. The following were Charles Sanders Peirce's conceptualization of how people came to believe things for the wrong reasons. Unfortunately, his list, like Bacon's, does not separate logical fallacies into what are now known to be the correct causal mechanisms. It is presented as his list, not as the best analysis of faulty logic. Recall again that he was not claiming that the belief was necessarily wrong, but rather the reason for the belief is unacceptable. Note that the inverse of his first two faulty reasonings were appended in the following list (within parentheses), and his a priori category was split into three distinct errors based on common usage and are given within parentheses.

1. Tenacity (and Novelty)

Belief or faith based on what was done in the past (tradition) in lieu of logic, understanding, or explanation. Belief in what was, is labeled belief via tenacity. An equally erroneous view is that whatever is new or nontraditional is correct.

2. Authority (and Antiestablishment)

This is unquestioning belief or faith in authority in lieu of logic, understanding, or explanation. Belief in what you are told simply on the basis of the speaker's credentials is labeled belief via authority. Again, an equally erroneous view is that the "establishment" position is always wrong.

3. A Priori (Subjectivism)

Belief or faith in knowledge derived from feeling states (i.e., to feel) in lieu of logic, understanding, or explanation. "I **feel** in my bones that this is true." Clinical or theoretical judgments are often justified with this excuse. Untold criminal justice (sic) films on TV are based on this reasoning. It is essential to realize that you would not want to go to jail just because your favorite TV cop felt in their bones that you were guilty. Belief in what you feel is right is labeled belief via subjectivism. An excellent, albeit obscure, example of this error is available in the film "One Flew Over the Cuckoo's Nest." Nurse Ratched was wrong because she felt her feelings were adequate justification for what she did to her patients. Similarly, if a mob lynches someone they are guilty of murder not because the person being lynched is always innocent but rather the mob terminated a life for an unacceptable reason: their strong feelings that the victim was guilty.

4. A Priori (Intuition)

Belief or faith in knowledge apprehended directly without experience or reason (i.e., to know) in lieu of logic, understanding, or explanation. "I **know** that this is true." Belief in what you know is right is labeled belief via intuition or via a priori knowledge. It would seem that those criminal justice (sic) films that do not base their decision on subjectivism base them on intuition. In Peirce's view, intuition differs from subjectivism in that there is no emotional basis for the belief, it is simply "known." This rationale differs from rationalism in that it was not "reasoned out;" it is simply and directly known. It is the same as the other two in the sense that it is unacceptable.

5. A Priori (Rationalism)

Belief or faith in knowledge acquired through reasoning process alone (i.e., to reason out) in lieu of logic, understanding, or explanation. "I **reasoned this out** so it must be true." Again, it is not that the result of this type of decision is necessarily wrong but rather that it is not necessarily right. Often people make erroneous but seemingly logical predictions because they misunderstand what is happening, are unaware of all the facts, or have imperfect logical reasoning skills. Belief in what you have reasoned out is labeled belief via rationalism. We each know some brilliant rationalist. They could convince uneducated people that night is day. Good salesmen and good lawyers are good at plausible arguments that are not necessarily true. The problem with rationalism is easily understood when you recall the time you talked someone into believing a lie by using what the other person thought was inescapable logic or when you recall the time you were talked into buying something for what you thought was a very good reason that you later came to realize had been wrong. Unfortunately, some people who claim to be scientists are reinforced more by winning theoretical battles than by uncovering truth. As a result, they don't examine the validity of their arguments as much as they should.

C. Classical Forms of Erroneous Reasoning

This third list of errors of reasoning and their classical labels (typically in Latin, of course) is the backbone of many introductory courses on logic and critical thinking. The following provides a partial list of erroneous logic or "informal fallacies" whereby conclusions can be made to appear correct.

1. Argumentum ad Baculum

A fallacy caused by an appeal to the use of force (e.g., vote this way or I will fire you).

2. Argumentum ad Hominem

A fallacy caused by noting some negative but irrelevant aspect of the person making an assertion and then implying that the statement is false because of that negative characteristic (e.g., that person is a Muslim therefore it is obvious that they are lying).

3. Argumentum ad Ignorantiam

A fallacy caused by an appeal to ignorance or a lack of information (e.g., no one ever disproved the Bermuda Triangle, so we can assume that it contains real paranormal effects).

4. Argumentum ad Misericordiam

A fallacy caused by an appeal to pity (e.g., you must agree with my clients in this lawsuit otherwise they will be poor and hungry).

5. Argumentum ad Populum

A fallacy caused by an emotional appeal to crowd-think, to popularity, or to the majority opinion (e.g., evolution is a lie because everyone I know believes it is wrong).

6. Argumentum ad Verecundiam

A fallacy caused by an appeal to an authority whose expertise is in some other area (e.g., you should vote this way because Tom Cruise votes this way).

7. False Cause (Post Hoc)

A fallacy caused by mistaking what goes before something, as its cause; this is formally labeled a post hoc ergo propter hoc error (e.g., last night was a full moon and crime was up therefore the moon must have caused it).

8. Complex Question

A fallacy caused by several conflicting questions rolled into one thus preventing a simple single “yes” or “no” answer (e.g., “have you stopped beating your wife?”).

9. Ignoratio Elenchi

A fallacy caused by drawing an irrelevant conclusion (e.g., murder is a horrible crime, therefore, the defendant is guilty).

10. Petitio Principii (Tautology)

A fallacy caused by arguing for a conclusion with nothing more than a synonym for the conclusion. It is also called circular reasoning, a tautology, or begging the question (e.g., God is perfect and wrote the Bible because the Bible says God is perfect and wrote the Bible, and because the Bible was written by God, then it must be true).

11. Equivocation

A fallacy caused by confusing the different meanings a word or phrase may have (e.g., the sign said fine for parking, so I parked there).

12. Amphiboly

A fallacy caused by the ambiguity resulting from the grammatical construction permitting two different meanings (e.g., if you get Sue to work for you, you will be lucky).

13. Accent

A fallacy caused by a changed accent changing the meaning of a statement (e.g., we should not SPEAK ill of our friends so I wrote them down for you).

14. False Equivalence

A fallacy caused by stating that two things are the same because they have one thing in common (but not everything in common). Set 1 could contain elements A and B while Set 2 could contain elements B and C. Russia under Stalin was Marxist and Stalin and Russia did some very bad things, therefore Marxism is bad.

D. Lies

There are also instances where the speaker deliberately makes statements that are known to imply what is not true.

1. Adding Information that is not Factual (lie of commission)

An error caused by stating something that is not true (e.g., Saying that John robbed the store when he did not do it).

2. Removing Information that is of Importance (lie of omission)

An error caused by stating something that omits something essential for its correct interpretation (e.g., a letter of reference that states “John was a hard

worker" (which he was) even though he also embezzled money).

E. Conceptual Follow-Up: The Invisible but Substantial Loss of Critical Thinking in the American Culture

Rhetorical explanations seem familiar and true because television programs and podcasts all too often emphasize these erroneous forms of knowledge. To make matters worse, the writers usually set it up so that these types of erroneous reasoning win. This leaves the belief that the reasoning was correct because in that situation it was successful. This fantasy is necessary in web land and television land because a generally uneducated audience cannot necessarily follow any more realistic albeit more subtle or complex type of logic. Producers of mass entertainment can either produce programs that are realistic and therefore appeal to only the upper portion of the potential audience, or use isolated, eclectic, illusory explanations for each event and therefore appeal to the far larger number of people on both sides and near the mean IQ and mean education level.

Web land and television land's incessant simple exposure effect is a problem because normally intelligent people are impressed over and over again, year after year, by fallacies being correct in the fictional shows. As a result, they start using those rationales in their everyday interactions without realizing that they have used the erroneous, make-believe fantasy as their role model for thinking straight. The effect is analogous to someone moving to a new part of the country and developing an accent associated with that part of the country. The impact on children of untold hours of super heroes shooting their way out of every disagreement has been discussed over and over by parents. The sad thing is that the much more damaging impact of untold hours of podcasters, heroes, newscasters and political pundits using error prone logic is ignored.

Media has been stealing peoples' ability to think critically for quite some time, and we all are the worse for it. We are all susceptible to idols of the cave and theater. It requires substantial effort to come to a correct conclusion.

III. Pseudo Explanation Via Specification of Future Causation or: Teleological Explanations

This type of explanation posits a cause in the future, so it is clearly wrong. The fact is that nothing can read the future. The future has not even occurred yet. Things cannot reach out of the future back through time to cause things to happen in the present. Recall the thought experiment of the naïve pigeon placed on an FR 500 schedule and expected to behave appropriately the first time. Even though food will be available in the future for 500 pecks, the pigeon will starve. You cannot place a human in a dungeon with no food or water and let them out only when they call some phone number that you will reveal to them only after they get out.

The future does not travel back into the past to cause the dialing of the correct ten-digit number. Obviously, the true cause of any behavior is experience with past reinforcement contingencies.

A teleological explanation is a shortcut description of what is actually the result of a history of exposure to the ontogenic and phylogenic contingencies. In this sense a teleological explanation is "backwards talk." What appears to be a common trend in a history of functional relationships becomes a future goal and eventually a future cause.

Note that teleonomic descriptions (covered in Section II. D. of the next chapter) should not be confused with teleological explanations. Teleonomic categorization does not imply causation in the future.

A. With Intentionality

These teleological explanations assume an internal entity that is aware of the future contingencies and knowingly acts so as to benefit from that contingency. These explanations are therefore unacceptable for two reasons. First, the future simply does not exist in the present. Secondly, it's of no value to explain why a person or pigeon does something by postulating that some knowing entity (e.g., mind) within the organism, because that simply changes the question to why does the mind do it.

B. Without Intentionality

This type of teleological explanation is invalid for the same reason that any teleological explanation is invalid: the future has not yet occurred and therefore cannot exist in the present and can therefore have no role in causation. Teleology without mentalism is still teleology. In actuality, the speaker unknowingly extrapolates the presumed goal from the existing data, and then states that the behavior was caused by that goal.

For example, a heat-seeking missile (i.e., an entity without a mind or intentionality) will change its course until it contacts the hottest emitter in the sky. It should be obvious that the guidance system was developed before the missile was fired such that it would turn toward heat and turn away from the cold. The missile is not seeking heat, rather engineers built a mechanism that turns toward heat because they had learned from their past experiences that that was what needed to be done to shoot down a plane.

People often say that water (i.e., an entity without a mind or intentionality) leaks into a basement because "it finally found" a hole and thereby flowed into the basement, thus "seeking the lower level" but that is a verbal shorthand that leads to confusion if we are seeking a cause. There is not an internal process directing the water toward a goal. We cannot assert that the water was moving in order to get to where it was going. Rather, we can only assert that predictably, if the water eventually appears at a hole for whatever reason, then the proportion of water molecules will increase on the side of the hole that is closest to the largest mass (e.g., will fall through the hole towards the earth) just as any other unsupported

object adjacent to a large mass such as the earth. The process controlling the water is not a future or a goal, what it actually is, is labeled gravity and fluidity.

IV. Conceptual Precursor: Fundamentally Different Epistemological Approaches to Explain the Causes of Behavior

There are two predominant approaches to explaining functional relationships involving an individual's behavior. Figure 9.1 illustrates the fundamentally different epistemologies of these two explanatory approaches.
They are labeled internal and external explanations. A more focused depiction of the external approach is given to its right and is labeled "radical" as in radical behaviorism. Internal explanations are not behavior analytic and are covered in the next section of this chapter External explanations are the raison d'etre or hallmark of behavior analytic explanations and are covered in the next chapter.

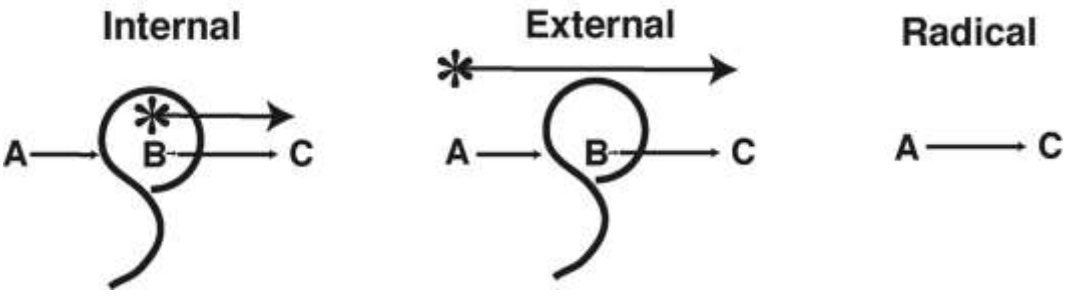

Figure 9.1 Two different epistemological approaches to explaining. behavior.

In simple terms, an internal approach tries to explain an organism's behavior (C) by reference to some internal entity (B) with little regard for how B got there. An external approach on the other hand tries to explain an organism's behavior (C) by reference to events in the environment (A) with little regard for what goes on inside the organism. A radical approach attempts to limit itself to predicting C data based on the A data rather than determining why the animal responded.

V. Explanation Via Appeal to Inner Cause, or: "Internal" Explanations

A. Types of Internal Entity

1. Empirical

This is physical internalism. The classic example is a physiological explanation for behavior. For example, "the behavior occurred because of activity in the brain." Alternatively, "the behavior occurred because of endorphins." Obviously, the existence of the brain can be empirically proven, and no one would suggest that the brain (or chemicals or quanta) have no role whatsoever in the behavior of the organism. The point is that empirical internal explanation must add substance and understanding to the issue of what will the organism do, and when will it do it, not simply make-up plausible sounding activities or even well proven physiological processes in the brain. It is important to keep in mind that: 1) a reference to the brain or some chemical that does in fact exist does not necessarily make that something the true internal cause of the behavior. An empirical internal explanation must show empirical evidence that that entity can actually be seen as the internal cause of the behavior. And, 2) the question remains – what caused the brain structure to "turn on" and for it to do those things that are purported to cause the behavior? Finally, 3) experimental proof is necessary to reveal whether structure causes behavior or behavior causes structure.

The weakness in empirical physiological types of explanations for the field of psychology is frequently masked by the prestige of medicine; the erudite sounding Latin names for various parts of the brain that only the cognazati know and can pronounce; the complexity in the brain pathways; and the pretty colored pictures that can be made from PET scans, regional blood flow, and MRIs. This weakness is only exacerbated by the relative lack of knowledge of those brain structures, the prestige of medicine, and the poor critical thinking in those swayed by those "explanations."

The task of behavior analysis is not to discover that the electrical charge on the available sodium ions will make Johnny's arm move. Neither is it to discover that the activity in the motor end plate or even the contraction of the arm muscle will make Johnny's arm move. Behavior analysis sees these functional relationships as irrelevant and missing the important point of why did Johnny's arm moved. Behavior analysis is defined by its exclusive focus on what environmental processes across immediate, short, medium, and long time scale made Johnny's arm move. All else is irrelevant. To some, musical sounds are caused by the passage of air across the vocal cords. However, to a behavior analyst it tells us nothing meaningful about why a caged bird sings.

2. Nonempirical

This is nonphysical internalism or conceptual internalism. This category includes any internal entity without actual empirical support such as the mind or cognitive processing center, and includes non-empirical physiologizing.

Ultimately this approach can be seen as tautological. Because cause and effect are both the same single observation with different names, the internal entity is simply given the properties necessary to explain the outcome. For example, the fact is that knowledge is behavior under the control of covariance in the environment. Knowledge as something in the brain is an inference.

a. With Basis Only in Folklore (Mentalism)

Unsupported phenomenological notions such as the mind are typical of this category. Spence referred to this class of explanation as animistic. These explanations are unacceptable because they have only flimsy, if any, support. Their support rests mainly in folklore and provides no actual evidence for the belief. For example, "when John's mind realized the solution, John's mind made John's body make the correct response" (often shortened to "when John realized the solution he made the correct response"). We of course know he realized the solution only because he made the correct response (thus revealing the tautology).

b. With Inferential Support (Cognitivism)

These speculations on the nature of internal machinery underlying behavior are generated from theoretical perspectives; they are more likely to be true than a wild guess but are not necessarily on firmer ground than primitive notions of the mind. The burden of proof is on those who argue that non-empirical internal entities are useful and true.

There are three critical issues facing this class of explanation that are rarely answered. The first is: is the proposed machinery actually true? Secondly: is the proposed machinery actually useful in either basic or applied areas? And finally: what environmental events in the real world cause those internal constructs to be what they are, or to do whatever they are thought to do to cause the behavior?

In sum, are there any proven independent functional relationships between the cause and the cognitive process and are there any proven independent functional relationships between the cognitive process and a behavior, and finally does the internal process add anything to the empirical input-output data?

c. Conceptual Follow-Up: The Difference Between Cognitive and Mentalistic Explanations

Both mentalistic and cognitive explanations are based on the assumption of a non-empirical internalistic process controlling behavior. Both explanatory systems presume that it is productive to know how internal machinery controls the behavior of organisms.

The difference between a mentalistic and a cognitive explanatory system is that a cognitive approach makes deductions based on the proposed internal process and then uses empirical experimental evidence to test what are thought to be the ramifications of that proposed internal process by affirming the consequence.

The validity of the ramifications, as well as the interpretation of the affirmed consequence, is open to question. Additionally, the actual usefulness of knowing how an internal process controls behavior is disputable.

B. Flaws of Internalism as an Explanation of Behavior

The following issues were originally developed by, and are more fully discussed by Donahoe and Palmer (20xx). It is intended that you use this section as a study guide when you read their treatment in their book. It is not suggested that they would agree with each point given below.

It could be believed any one of many internal entities or verbal processes is the root cause of our behavior. For example, we could: 1) claim that a conscious mind thinks something through, arrives at a decision, and then activates some behavior. 2) We could claim that a cognitive processing center arrives at a decision and then activates some behavior with or without some consciousness. 3) We could simply state that the brain did it. 4) Finally, we could argue that a receiver made of invisible dark matter in our brain is taking directions from space aliens who are also made of dark matter. All of these are considered internal explanations.

It is important to note that the following list enumerates the flaws of internalisms as explanations for behavior. It should not be construed as suggesting that there is no brain within an organism, or that there is no empirical evidence that removing someone's cortex will have an effect. Additionally, it should not be construed to be asserting that someone cannot count to ten "in their head." Finally, it is not asserted that there is no such thing as an invisible dark matter receiver. The issue is not whether "private events" exist, rather the issue is whether it is productive to consider those private events a cause of behavior or even if it's worth getting into an argument with someone over the details/reality of a non- objective event, after all, it cannot be proven one way or the other. After hours, days, years, or even millennia of wrangling over internalisms are you better off than if you had used the time to document functional relationships?

1. Internalisms are Not Necessarily Resolvable/Falsifiable

While these flaws apply most clearly to non-empirical internalisms, many empirical internalisms are invoked in a purely speculative fashion and are devoid of the characteristics that would make them either provable or falsifiable with empirical tests.

a. Unfalsifiable Internalisms

We would immediately understand the unacceptability of the unfalsifiable internal explanatory approach if the example were perceptual. We have all been down that road. For example, if someone showed you a red card and you said red, they could argue that in your brain you actually saw green and that you were just taught to say red when you saw green in your mind. Someone else could assert that you actually saw blue in your mind but were taught to say red. The two of

them could argue forever over whether your mind really saw green or blue. In actuality, because there is no empirical anchor that can be used to prove one view over the other, the issue cannot be resolved, and because it cannot be resolved, it is meaningless. Concern for the actual image we see in something labeled the mind or cognitive color processing center is, therefore, a metaphysical question, not a scientific one. The relevant facts are presenting colored cards to a person and documenting the answers from that person.

In addition to the simple issue of having unfalsifiable internal elements is the addition of unfalsifiable internalisms after the fact whenever the theory fails. This defect is based on the apparent permissibility of adding an unfalsifiable internalism whenever a prediction fails. Many cognitive theorists fall into this self-serving trap by simply coming up with another free parameter whenever their predictions fail, rather than to accept that their theory was falsified and is therefore wrong. The acceptability of unprincipled ad hoc proliferation of non-empirical constructs makes any theoretical approach that permits it not only unfalsifiable in principle, but optimizes it to be so and is therefore shameful.

The unacceptability of postulating ad hoc unfalsifiable principles whenever needed can be illustrated with a theoretical free parameter game which inevitably ends in a theory with too many free parameters. Consider the following figures as the evolution of a bloated internalistic explanation, and an illustration of how a theory can be amended with whatever is necessary each time it is falsified so that at some point it becomes obvious that it, in principal, could not be falsified by any future result whatsoever. As a result, the too easily modifiable theory generates only the illusion that the theory successfully passed every test.

In this game, the "bad theorist" team's job is to come up with a theory that predicts whether a marble will roll out the other side of what is called a black box, (because the inside cannot be seen). In this game, the inside of the box is exactly as pictured below (a straight through pipe). It is easy to make a reliable prediction of the obtained behavior (i.e., marble coming out) by simply noting the environmental cause (i.e., whether or not a marble is rolled into the black box). If it is rolled into the box, then it will roll out the other side; if it is not rolled in, then it will not roll out the other side; end of story. In this simplest of all possible situations, the explanation need not have any conditional exceptions. As a result, it is self-evident that any free parameters are unnecessary and are therefore known be wrong or, as a generous minimum, are unparsimonious.

The theoretical expertise of the bad theorist team can quickly be evaluated by letting them roll a marble into the box and use their prediction system to predict whether or not the marble will come out the other side. In this game, they win or lose money and academic credibility based on the accuracy of their predictions. (Note that this test would be pretty easy for a behavior analyst to pass.)

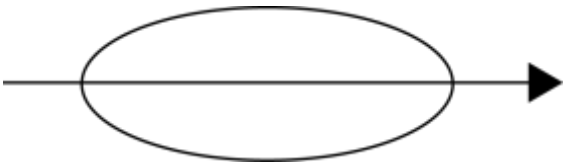

Figure 9.2 An illustration of a simple game. The device passes any input directly to the output. There are no internal stages. It functions like a marble rolling through a piece of pipe. The machine has zero bits of information. (If rolling the marble in or not is excluded.) If the marble is rolled in, then the marble will roll out; if there is no marble rolled in, then no marble rolls out.

Suppose the bad theorists use chicken entrails on the floor, or the shape of the clouds, or in this example a coin flip to make their predictions rather than simply noting the obvious relationship between input and output (i.e., if the ball rolls in, it will subsequently roll out). They never really attend to the environmental history (i.e., if the ball rolls in or not), rather they concentrate on their theory; (a coin flip). Because they are not basing their prediction on the true cause, the bad theorists are by definition making random guesses and will be right half of the time and wrong half of the time because chicken entrails, clouds, and coin flips are not related to the actual cause: the ball rolling in. Unsurprisingly, they make errors when trying to predict if the marble will roll out the other side when they based their prediction on their theory (which is obviously useless) rather than basing their predictions on what happened in the environment. (Recall that the black box works such that: if marble in, then marble out; and if no marble in then, no marble out.)

Let's say that after the first test of ten rolls, they get half of them wrong (which comes as no surprise). But before you can take points away from them because the obtained data had falsified their theory because of its bad predictions, they explain their failure by saying there must be some internal process (see Figure 9.3) in between the input and output called "memory" and that stage can let the bearing pass through or not based on the state of the memory.

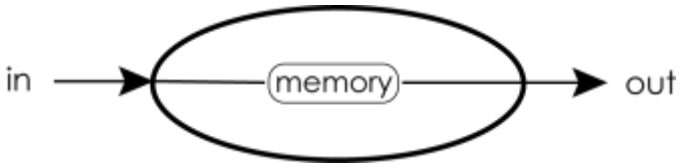

Figure 9.3 The in-out machine with one internal decision stage added. An input is passed to the output if the "memory" is open. The output is blocked if the "memory" is closed. The machine has one bit of information or two possible outputs given an input.

You, in the spirit of trying to help colleagues develop explanatory theories, stipulate that the memory is always open (after all it is only an open pipe) but using their bad theory (coin flip) they still make bad predictions of what will happen when they roll ten more marbles into the black box again. They get half of them wrong again. But again, before you could subtract points from the bad theorist team because the obtained data had falsified the theory, they claim that there was also an encode and a decode state inside the black box. They then claim that they could not be expected to predict correctly under those conditions and you can't dock them points just because they failed to predict the output because you did not tell them the state of the encode strategy and the state of the decode strategy.

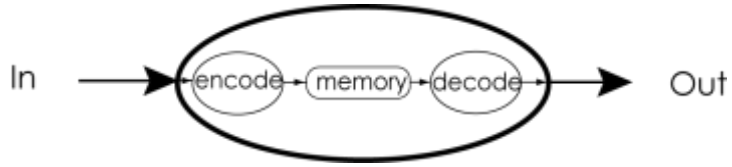

Figure 9.4 The single in-out machine with three stages added. The information may or may not be encoded, the information may or may not be retained in memory, and the information may or may not be decoded. The machine has three bits of information or eight possibilities each of which would have to be understood to predict the output.

You then stipulate that the encode and decode strategies are always open and that the memory is always open. But again, based on their coin flips, they make rotten predictions. But before you could subtract points from them for their falsified theory, they say there must also be motivation inside the organism that made them not responsible for their bad predictions, etc., etc.

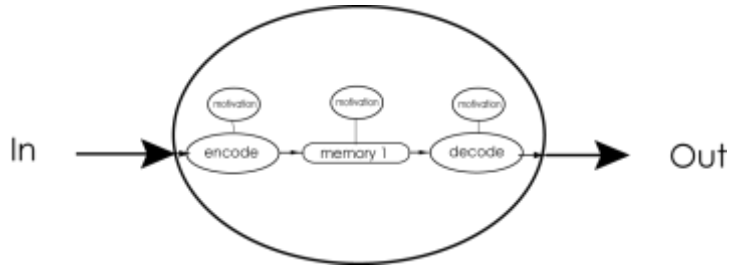

Figure 9.5 The simple in-out machine with a motivation mechanism governing each of the three stages in the preceding machine. The machine now has six bits of information or 64 possibilities each of which would have to be understood to predict the output.

After giving them the state of motivation, and the state of the encode/decode strategy, and the state of memory, they still make terrible predictions when they try to predict what will happen when they roll a marble into the black box (after all their theory is based on the state of a coin flip!). After this failure, they assert that there were several different types of memory (declarative, episodic, and retrospective) and they are not responsible, etc., etc.

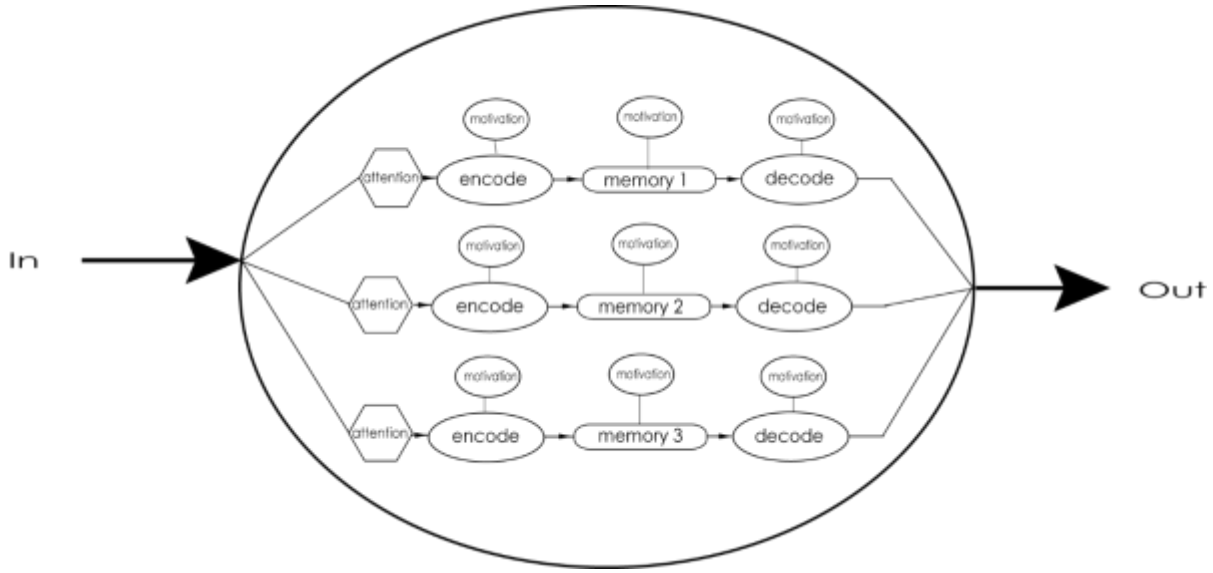

Figure 9.6 The simple in-out machine now with three different types of memory and with an attention stage added to each type of memory. This machine has 21 bits of information, or more than 2 million possibilities each of which would have to be understood to predict the output.

Obviously, this game could go on forever. This unconstrained proliferation of after the fact processes added to account for specific results (ad hoc) makes it simple to make excuses for any event. They enable the illusion that scientific progress is being made. Because if the after the fact explanation had been invoked before the results, then those results would have been "predicted." This game proves that the proliferation of internal constructs is not necessarily a reasonable solution.

Clearly the marble and black box game is simplistic, but it needed to be so to conclusively prove its points. In actual situations, the input to an organism is complex and occurs across several time scales and includes multiple events. Additionally, the output of an organism is more complex than simply a marble rolling out immediately after it rolled in. But, it would be instructive to count the number of types of memory, and the number of parameters in current use in memory research.

The point of this section has been to show that ad hoc internalisms are unfalsifiable and therefore useless to productive theorizing. Whether there is one, many, or always "just one more," the problem is the same: unless they are falsifiable, they are meaningless.

Note that a behavior analytic approach to memory is to manipulate environmental precursors to construct a coordinated set of covariates such that the output could be predictably changed as a function of changes in the environment, rather than to simply proliferate unfalsifiable internal constructs.

2. Internalisms are Not Productive

First, note that the theory illustrated in Figure 9.6 would require you to

understand 21 causal relationships and their interaction to predict the output. Theories are supposed to help us predict, not make it impossible.

Secondly, a problem with internal causation is that it typically leaves open the question of what caused the brain process or mental process in the first place (which eventually resulted in the behavior). If the explanation for a pigeon pecking a green light is that the brain made the pigeon do it, or that a person's mind made them sing, then the obvious question is what made the brain or mind peck or sing? Besides, what good is knowing only the output of an organism and not what in the environment caused it? It's rather like saying that the bird pecked because its neck muscles contracted or the person sang because air flowed past the vocal cords. The question simply becomes what made the neck muscles move or what made the air pass through the vocal cords? What makes being satisfied with "the brain did it" or "the mind did it" any more intelligent sounding or useful then "the neck muscles did it." in every case, you want to know the environmental history that caused the head to move or the person to sing.

Knowledge is "knowing" that if you want more Y, then you give more X (e.g., you want the car to go faster, so you step harder on the gas pedal). If you know that the engine makes the car go faster, but you do not know how to make the engine go faster, then you do not know how to make the car go faster. If the unobserved verbal activity that is thought to cause behavior is not tied in a one-to-one manner with events in the environment that caused that internal verbal activity, then that unobserved verbal activity cannot be precisely known or controlled. If it is unknown, then we have nothing with which to predict the output behavior and nothing with which to control the output. The knowledge of an internal state is not useable.

Knowing that your phone has a RISC or a CISC processor is not helpful. Knowing how to swipe through the menu with your fingers is helpful.

3. Internalisms Divert Attention

A position that would assert that output behavior is controlled by unobserved verbal activity or cognitive processes that are not under the control of the environment or that that relationship is unknowable (either unknown or free will), abandons the opportunity to develop accountable, predictive models. If you wanted to use your new phone in a hurry, would you read about the electronic structure of the RAM memory or read about what external finger movements you use to make the camera work?

4. Internalisms are Irrelevant

Even in the case where internalisms are useable in basic or applied areas, if the unobserved verbal or cognitive activity that is thought to control the output behavior is under the control of environmental input, then the internal verbal activity becomes an irrelevancy in prediction.

If:

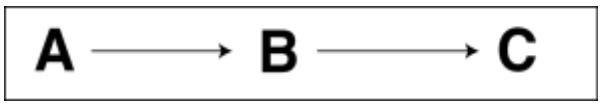

Figure 9.7 An illustration of A causing B and B causing C.

then, a more parsimonious and therefore more efficient model is:

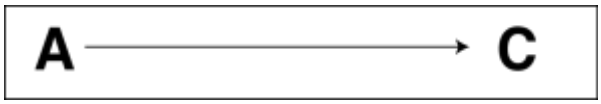

Figure 9.8 An illustration of the effective case in the above figure, i.e., A causes C.

As was presented earlier, suggesting that B is necessary in order to account for the modulation of the process is erroneous. It is easier (as well as being on a sounder footing) to simply state that an external modulating influence modulates the effect, rather than making up some internal tautology to carry out that modulation.

5. The Justification or Necessity of Internalisms is Arbitrary

An additional problem with a belief in the usefulness of internal explanations is that their necessity is arbitrary. If a mechanism operating at a more internal level is always better and always necessary, then obviously, a process more internal than the brain, the mind, or the cognitive processing center must be sought. We would be obligated to explain things chemically or with a subconscious mind or with a subcognitive processing center, but then if internal explanations were better, we would be obligated to explain those things with quantum physics and a subsubconscious or a subsubcognitive processing center. If one cannot accept a simple input/output (external) answer at some level, then one must go all the way to the bottom. If you do not go all the way to the bottom, the stopping point is a matter of personal bias not epistemological validity. Behavior analysis simply uses for the body what internal explanatory systems use for whichever level of internal entity at which they arbitrarily choose to stop.

Note in the figure below that in every case the maximally inner entity is typically postulated to work solely in terms of inputs and outputs, which is exactly what (as we will subsequently see) an external view of the entire organism has argued all along (note that the lowest level used in each figure (the gray circle) are inputs and outputs with no internal machinery).

In this sense, internal explanations simply pass the problem to some poorly understood and unmeasurable internal level. After all is said and done, all theories do nothing more than account for the relationship between inputs and outputs. Arguing that a behavior is caused by some internal process is simply obfuscating what is at the bottom an external explanation at some level anyway. The following figure (Figure 9.9) could be based on either empirical internal mechanisms (cells, chemicals, quanta), or on non-empirical internal mechanisms

(cognitive, subcognitive or subsubcognitive), or a regress of dark matter space alien receivers within dark matter alien receivers.

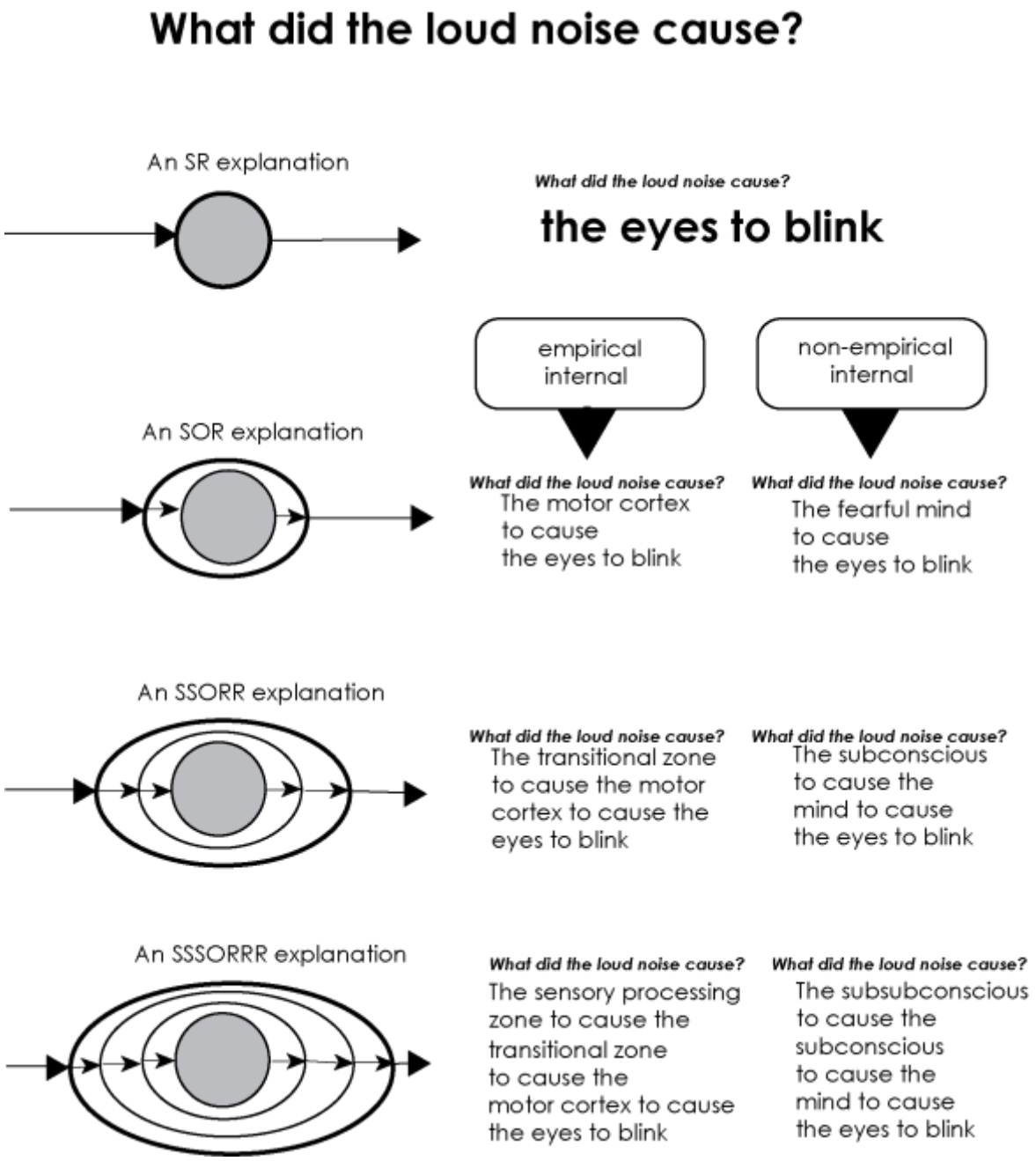

Figure 9.9 An illustration providing for a comparative analysis of a series of increasingly recursive reductionisms. The top portion of the figure is an externalistic explanation and simply states that the loud noise caused the eyes to blink something that anyone can observe and which can be falsified. The second row shows an internalistic explanatory system. To the right of that illustration is the pseudo-explanation generated by that internalism if it is empirical or non-empirical. Each successively lower row adds an internalism within the internalism.

The three lower rows of Figure 9.9 explain the behavior of the organism by referring to some internal entity, an entity within the internal entity, or an entity

within the entity within the entity within the organisms that causes the eye to blink. Note that the final cause in all four figures (the input output functional relationship of the gray circle) is identical: an input-output relationship that does not appeal to some internal mechanism for validity. The gray indicates that no internal process is considered below that level.

6. Establishing the Reliability of Internalisms is Problematic

Typically, when internalistic research has either specifically examined a theorist's postulated internal mechanism, or a subject's verbal processes with respect to what they do, feel, or say, the findings have been consistent with that particular researcher's theoretical assumptions, but not necessarily consistent with other assumptions of other cognitive researchers. As if this alone were not bad enough, many researchers do not put much effort into resolving the discrepancy between the fundamentally different non-empirical entities of various internalistic researchers. As a result, many internalistic accounts fail for the same reason, introspection failed; a basic requirement of science is that results must be reliable and consensually valid. It is not reasonable to assert that there are 10,000 internalistic systems causing behavior, one for each of the researchers working in that area. This very fundamental issue bears repeating, if all the various cognitive theories are not closing in on a single theory, then they are driven more by the theorist's ego than by finding the truth.

7. Internal Verbal Activity as a Cause of Behavior is Inconsistent With Empirical Findings

As documented below, it takes little effort to show that the empirical evidence does not support unobserved verbal activity as a cause of behavior or as a useful explanatory model. The point is not to show that it is impossible to say to yourself "I will pick up my pen" and then you pick up your pen. Rather, the point is that internal verbal activity does not always correlate with the behavior of the person.

a. Internal Verbal Activity is Non-Empirical and Tautological and is Therefore Ineligible to be a Cause of Behavior

The support is nothing more than popular folk beliefs, and is generated by the data it is intended to explain.

b. Internal Verbal Activity as a Cause of Behavior is Inconsistent With Evolution

Brain structures mediating verbal behavior developed very much later than much of the brain. The ability to behave evolved well before the ability to "reason" and language (e.g., cognitive processes). Additionally, based on the anatomical evidence, it is unlikely that verbal behavior centers of the brain are in touch with

older centers. There are too few neural tracks connecting those areas. As a result, it is reasonable to assume that verbal centers of the brain do not control significant portions of our behavior.

c. Internal Verbal Activity as a Cause of Behavior Has Been Invalidated by Split Brain Research

For medical reasons, some people have their corpus callosum severed. That procedure eliminates any communication between the left and right hemispheres of the brain. In a sense, it creates two different people in the same body. Note that because of the way the CNS is wired, the brain hemisphere controls the hand on the opposite side of the body, and the language center typically develops asymmetrically, usually only the left hemisphere "talks."

A child with a split brain had only his left hemisphere exposed to a picture of a chicken claw and only the right hemisphere exposed to a snowy scene. Later, when given a set of pictures to match by pointing to them, his right hand (controlled by the left hemisphere) chose a chicken while his left hand (controlled by the right hemisphere) chose a snow shovel. Both were correct behaviors given the specific exposures the two different sides of the brain had received earlier.

When asked why he pointed to the chicken, he (the left brain) said, "it goes with the chicken claw." When he (the left brain) was asked why he pointed to the shovel, he (the left brain) responded, "to clean up the chicken coop." Note that in reality his left hand pointed to the snow shovel because his right hemisphere had been exposed to a snowy scene.

What had apparently happened was that his left hand pointed to the snow shovel because his right hemisphere had been exposed to a snowy scene. His left hemisphere (the talking one) had seen the left hand (under the control of the hemisphere that had been exposed to the snowy scene but that could not talk) pointing to this shovel and having no data from the right hemisphere, the left and "mentally thinking" hemisphere proceed to confabulate a perfectly good sounding (albeit erroneous) excuse for the behavior.

This study revealed the erroneous and tautological foundations of mentalistic psychology. Conscious thoughts or verbal behavior can be shown to be different than the true cause of behavior and therefore cannot be presumed to cause any particular behavior. A thinking process (i.e., "oh yes, the shovel will be used to clean up after the chickens") did not determine the behavior of pointing to the snow shovel because other items were more closely related to chickens. Rather, the snowy scene controlled the snow shovel choice. The mental verbal process that the child asserted caused the behavior (i.e., shovel to clean up after chickens) was proven to be created **after the fact**, even though the child "truly believed" that the confabulated thought caused the behavior.

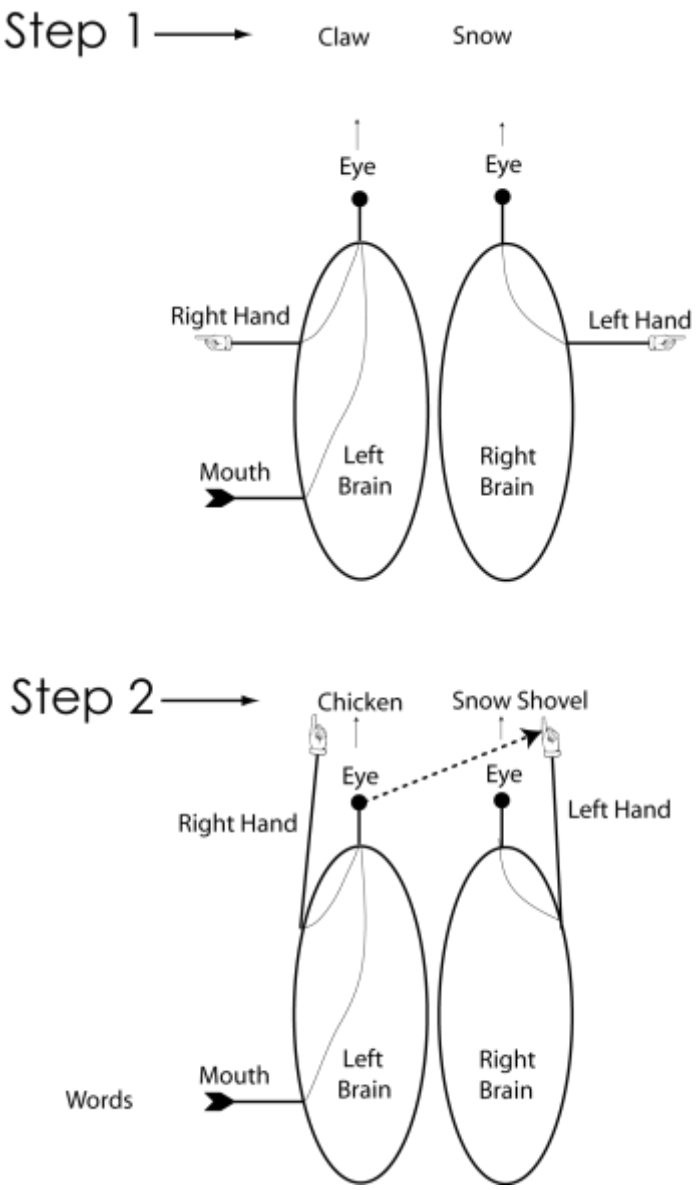

Figure 9.10 A depiction of the separated left and right cerebral hemispheres and their intact connections to the left and right eyes and hands, and the left hemisphere's control of speech. In Step 1, the person is shown a claw and snow. In Step 2, the person is shown a chicken and a snow shovel. Note that the left eye can see the left hand.

8. Conscious Realization or Awareness as a Cause of Behavior is Inconsistent with Empirical Findings

Again, as with internal verbal activity, the point is not to show that there is no such thing as awareness or consciousness or that it is impossible to ever be aware of some event or functional relationship. Rather the point is to show that awareness cannot explain a meaningful amount of behavior and is, therefore useless as an explanation.

a. Conscious Realizations Controlling Behavior Has Been Invalidated by Protracted Extinction

Imagine a demonstration where a person is seated in the front of the classroom with a bell and a metal plate on the desk. Imagine further that an electrical apparatus is connected to the bell and plate. Suppose the subject rests their hand onto the plate, the bell rings, and a shock is delivered through the plate. Suppose that procedure is repeated 50 times. Now the apparatus is removed to the hallway outside the classroom. The subject explores the desk and confirms that nothing of the apparatus remains in the room. The subject and presumably the subject's mind and verbal processing center is asked to repeat, "there is no shock possible" continuously. If there were a verbal mind that controls behavior, we have guaranteed that the subject's mind knows that no shock is possible. The subject then sits at the desk with their hand on the Formica surface after which a bell rings. What do you guess will happen in spite of the subject's verbal and mental activity? In spite of verbal beliefs and statements, the behavior of a withdrawing hand will persist until it extinguishes exactly as a behavioral view would predict. The mentalistic approach would have predicted that the mind would realize that no shock was possible and would therefore not direct the hand to withdraw.

Because the hand withdrew, then the issue becomes: if some behaviors are not controlled by the mind, then the verbal mind must be abandoned as a universal cause of behavior or else some principled system must be provided for selecting which behaviors the mind is thought to control and why. Absent the principled system, the mind as a cause of behavior is useless. With the principled system which specifies what environmental conditions lead to which behaviors, the mind is not a necessary element in the prediction. The mind is irrelevant.

b. Conscious Realizations Controlling Behavior Has Been Invalidated by Self-Destructive Behavior

Ask anyone who smokes cigarettes if they think that it is healthy. The vast majority will respond with something like "smoking is unhealthy, it is hurting me, and I wish I could stop." If verbal and mental activity were controlling their behavior, then they would stop smoking and would have stopped years ago when their mind started saying I wish I could stop. When the internal entity that is thought to cause behavior says it doesn't want to do some behavior that the body persists in doing (such as smoking), the theorist who is committed to an internal explanatory system must resort to a pretty twisted explanatory system by obscuring the cause of behavior by hiding it one layer further down within the homunculus (i.e., a mind within the mind which controls the body). Freud did exactly this when he asserted that there was a subconscious. Thus, by claiming the subconscious has a need to suffer a slow death from cancer, incompetent theorists can continue to enjoy the allegiance of gullible and ignorant adherents and the gullible and ignorant adherents can enjoy a good standard of living with very little effort on their part by defending this nonsense. Presumably if the subconscious could also be shown to not want to smoke possibly with hypnotism, the non-behavioral theorist would not hesitate to postulate that the cause was a

death wish in the sub-subconscious, which controlled the subconscious, which in turn controlled the mind, which in turn controlled the body.

c. Learning Occurs Without Conscious Realization and Therefore Conscious Realization Cannot be a Necessary Cause of Behavior

It is relatively simple to remove a phobia without the therapist talking about it or the patient being able to articulate what happened. Similarly, it's easy to establish an operant behavior without the person being able to articulate why they are emitting that behavior.

d. Stimulus Control Occurs Without Conscious Realization and Therefore Conscious Realization Cannot Be a Necessary Cause of Behavior

Some people report that they cannot see a single thing (i.e., everything is totally black) but oddly enough they can in fact be conditioned to act appropriately to some visual stimuli. This phenomenon is labeled "blind sight." If the mind of a person with blind sight can see when it's being conditioned, then why won't it help the body have a better quality of life by warning the body when it's about to trip over a curb.

e. Extremely Complex Adaptive Behavior Occurs in Decortecated Animals

It can be shown that a decorticated cat (no possibility of consciousness) will scratch a stimulated spot on its side rather than a random spot or the easiest one to reach, it will also walk when pushed from the back, and will exhibit many other reflexes. All the behaviors occur without the possibility of consciousness.

f. Conscious Realization as a Cause of Behavior is Counterfactual

The flaw in internal explanations, especially introspective mentalism, is also illustrated with a simple request that your mind tells you the answers to neurophysiology question so that you can pass the Biology final exam (after all the mind must know which neurons are connected to which things. Alternatively, you should be able to control some physiological process such as smiling naturally when in an awkward situation, stop being hungry so you can lose weight, decreasing your blood pressure, or even to stop giving yourself irritable bowel syndrome in the middle of your graduation ceremony.

If the mental processing center is unwilling to do what you are fervently saying to yourself or cannot understand physiological processes, then it is not reasonable to argue that the conscious mind controls your behavior.

CHAPTER 10

Behavior Analytic or External Explanatory Mechanisms

I. Explanation Via Specification of External Functional Relationships, or "External" Explanations

A. Conceptual context: Time scale of the external functional relationship of interest
   1. immediate
   2. short
   3. medium
   4. long

B. Conceptual context: the expression versus the emergence of a functional relationship

C. The three functional relationships fundamental to behavior analysis
   1. functional relationship 1: response reinforcer or Thorndikian contingency
   2. functional relationship 2: stimulus reinforcer or Pavlovian contingency
   3. functional relationship 3: stimulus control

D. Unit of behavior
   1. conceptualization of behavior in terms of common end state; teleonomic or functional descriptions
   2. conceptualization of behavior as an act
   3. conceptualization of behavior as an act "related to the unconditioned response"

E. Assembly level of the explanatory unit
   1. molar or relatively large explanatory unit
   2. molecular or relatively small explanatory unit

F. Exclusive focus on external functional relationships
   1. the mind-body quagmire
      a. not biological as opposed to psychological (i.e., body vs. behavior)
      b. exclusive focus on behavior, body is irrelevant
   2. intervening variable / hypothetical construct slippery slope trap

G. Conceptual follow-up: behavior analytic externalistic functional conceptualization of causation, and explanation, and the passing over in silence the unproven or the unprovable

H. Conceptual follow-up: useful grammar for productively conceptualizing the behavior of organisms
   1. avoid reference to the animal
   2. avoid the active voice with respect to the animal

II. Conceptual Contrasts Between Behavioral and Other Explanatory Approaches

A. Internal empirical (biological) versus external empirical (behavioral) explanations
B. Internal non-empirical (mentalistic) versus external empirical (behavioral) explanations
C. Internal non-empirical (cognitive) versus external empirical (behavioral) explanations

III. Models as Explanations

IV. Conceptual Review

A. Principles of behavior analysis
    1. Behavior analysis is a deterministic and principled science
    2. Behavior analysis requires objectively demonstrated entities and is therefore strictly externalistic
    3. Behavior analysis establishes explanations, causes, and meaning via the functional properties of objectively demonstrated entities
    4. Behavior analysis is concerned with understanding the moment-to-moment changes in an individual organism's semi-permanent adaptation to covariance in the environment that emerges and is lost across the seconds-to-days time scale ("learning")
B. Review of examples of behavior analytic explanations as opposed to non-behavior analytic explanations
    1. single neuron organism
    2. referent of knowledge
    3. cause of egg retrieval
    4. cause of operation of water dispenser
    5. cause of smart phone functions
C. Grammar for clearly conceptualizing the explanation for behavior
    1. subject of sentences should be behavior rather than the animal
    2. organism in passive rather than active voice
D. Historical origin of behavior analysis
E. Conceptual distinction: radical behaviorism versus simple behaviorism (Palya's version of the distinction)
    1. Conceptual follow-up: Best practice versus common practice
    2. Historical evolution of the conceptualization of the cause of an individual organism's behavior

CHAPTER 10

Behavior Analytic or External Explanatory Mechanisms

In a sense, this chapter that details behavior analytic explanatory mechanisms could be seen as the core chapter of this entire text. The previous chapters could be seen as the necessary conceptual precursors and the subsequent chapters as the necessary conceptual follow-ups.

I. Explanation Via Specification of External Functional Relationships or "External" Explanations

Behavior analysis establishes explanation, causes, and meaning via the functional properties of objectively demonstrated empirical entities. The actual details enumerated in the explanation depends on the nature of the question.

The most useful, and therefore the most desirable class of explanations are those that provide the specification of the empirical environmental variables that control when and how the behavior of an individual emerges or is expressed across the short term by way of the specification and quantification of the contingencies of reinforcement, and a specification of the factors governing how that functional relationship generalizes to other situations.

The left portion of Figure 10.1 portrays a traditional depiction of a behavioral explanation for the cause of the behavior of an organism. The right portion of the figure provides a more punctilious depiction of a radical behaviorism view of behavior. Note that the right frame is limited to the behavior of an organism and its environmental history and context. The right depiction can not lead to questions pertaining to how the inside of the organism causes a behavior. The task is to predict behavior by reference to the environment not some internal mental or physiological state.

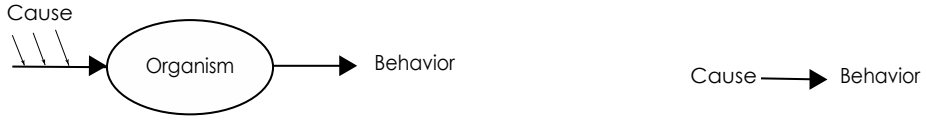

Figure 10.1 An illustration of an externalistic explanation of behavior. Environmental events in the history of an organism are seen to cause behavior.

External explanations are used in behavior analysis because they are unassailable, factual, or true and provide for irrefutably principled explanations.

1. it is not because the animal does not exist
2. it is not because the animal has no brain
3. it is not because whatever thinking is, does not exist
4. it is not because whatever consciousness is, does not exist
5. it is not because we are trying to hide the fact that space aliens control behavior

Even the most ardent theoretical opponent cannot disagree with the proof for the empirical "if ... then" statement. All they can do is to assert that some internal process **could** be considered the cause of the behavior. The nature of science would require that they prove their assertion before it was considered true and even then the behavior analytic cause would still be equally true.

Internal explanations are avoided because they are irrelevant.

1. it is not because science does not yet know enough about the brain (even though it is true that we know little about the brain)
2. it is not because the mind and cognitive processes have not yet been proven to exist (even though it is true that the mind and cognitive processes are unproven).

The situation is rather like a ancient vintner upon noticing a previously unknown cause-effect relationship that the taste of wine varies substantially as a function of the exact composition of the fertilizer, starts a research program based on varying the precise composition of the fertilizer. Neighbor vintners opine that the wind and humidity, and the love given to the vines affect the flavor of the wine. The original vintner would retort "that may or may not be true, but in any case, I have chosen to research and understand how the contents of the fertilizer changes the flavor of my wine. It is known to account for a substantial portion of the flavor of wine and it's something I can do something about. I can systematically vary the fertilizer and measure the wine and adjust the fertilizer based on what is known to work. I simply don't care about all those other possibilities that can't be proven one way or the other. It's what I choose to do. I'm sticking with what is known to be true, something I can do, and what has been proven to work. I am avoiding guesses which have not been proven to work, that I can do nothing about, and which are not known to account for the flavor.

To reiterate once again, the functional relationships between the environment (inputs) and obtained behavior (outputs) of an individual are the necessary and sufficient elements of an explanation of behavior, all else is irrelevant. It is the case that the right portion of figure 10.1 is all we actually have.

It is the specification of inputs to the organism that explains the output of an organism. These explanations are sometimes also labeled comparative (“what are the characteristic properties”), or functional (in what way does y change as a function of changes in x, or what is the mathematical function that describes how y changes with changes in x). Unfortunately, the term “comparative” frequently also refers to a genetic determinate and the term “functional” often also refers to the purpose that the behavior serves, especially in the evolutionary sense.

A. Conceptual Context: Time Scale of the External Functional Relationship of Interest

Explanations provide a cause and an ability to generalize that cause-effect relationship to other situations of interest. The time scale of the cause and situation of interest can vary widely. Historically, behavior analysis has had an almost exclusive interest in short time scale adaptation because by far, most of the variance in an individual's behavior, within its species, is attributable to adaptation at a short time scale. In more recent times, the behavior analytic methodology is coming to be applied across the entire range of time scales of adaptation.

It should be noted however that the vast majority of explanations and research effort pertain to short time scale adaptation and presume that immediate, medium, and long time scale adaptations are held constant.

The following are examples of research and explanations focused on a key peck following the onset of a red light across each time scale.

1. Immediate

If the interest is on the immediate or efficient cause, simply specifying that the red light was illuminated which the pigeon immediately pecked is a sufficient explanation. For example, the pigeon pecks because the red light was illuminated rather than the green light. The stimulus properties of the light with respect to wavelength and intensities are obvious potential independent variables. The focus is on the response itself and not how it came to occur across some time scale.

2. Short

If the interest is not simply understanding the reaction to the red light being illuminated (its expression) but rather on how the pecking to a red light when it was illuminated emerged, the explanation would most likely cover the reinforcement history of the pigeon in that that is a primary explanatory focus of behavior analysis. For example, the pigeon pecked the red light because it had a history of reinforcement for that behavior to the red light rather than pecks to green.

Variations in the schedule of reinforcement would be obvious potential independent variables.

3. Medium

If the causal factors were obviously not as simple as only a specific short time scale history of reinforcement with respect to the red key, a medium time scale explanation may be needed. The pigeon may have had a wide variety of reinforcement histories with a common element of reinforcement following a reaction to a stimulus change or to a wide variety of red things even though specific short time scale training to a red key had not occurred.

Alternatively, over the course of 30 or 40 reversals of a red green discrimination, the correct behavior to the stimulus alternatives may be acquired after only a single reinforcer. Similarly, following 30 or 40 peck red/extinction cycles only a single reinforcer will reestablish asymptotic responding to red. This higher order functional relationship is not the same as short time scale adaptation it does not reverse across a short time scale.

4. Long

If it became apparent that a learning or developmental history with respect to pecking stimulus changes were not sufficient, it may be that an evolutionary explanation for the pecking to a red key would be needed. It may be that it could be demonstrated that there was a reproductive advantage to pecking a red spot on a parent's beak and by altering that reproductive advantage, pigeons could be bred that would or would not peck a red key when it was illuminated, or that jumped to a red light going on from birth even in the absence of ontogenic experience with respect to the red key being illuminated. If the difference between subjects includes a difference in species, then this time scale is likely to be essential in explaining the difference in the behavior of the two different species.

B. Conceptual Context: The Expression Versus the Emergence of a Functional Relationship

The defining characteristic of a time scale of adaption is the time it takes for the functional relationship to emerge and to be lost. For short time scale adaptation, asymptotic behavior is obtained following the exposure to an effective relationship between stimuli or behavior and a subsequent event labeled a reinforcer across a seconds-to-days time scale. For example, the acquisition of key pecking to a green key as the result of reinforcing key pecks. The adaptions show relative permanence and persists across seconds to days even after the effective relationship with a reinforcer is removed, but the relationship is lost within a short time scale.

The expression of short time scale adaptation is defined as the asymptotic function relationship obtained to a stimulus following exposure to an effective relationship with a reinforcer. For example, the asymptotic pattern of pecking between fixed ratio reinforcers

C. The Three Functional Relationships Fundamental to Behavior Analysis

The task facing behavior analysis is to understand short time scale adaptation. In other words, to understand how specific details of contingencies of reinforcement and the cumulative effects of those contingencies can come to create the ontogenically-acquired behavior of an individual organism. The task is to identify what characteristics define an effective causal relationship with respect to those behaviors. Additionally, it is essential to have some way to characterize the result of the obtained relationship.

To the degree an explanation is a guess, it is not really an explanation; to the degree the explanation appeals to some other level of molarity that is not a relevant element of the cause, it is irrelevant because it does not provide the data at the same level as the functional relationship of interest.

Specific relationships between the three elements given below in Figure 10.2 have been shown to be the necessary and sufficient elements for the appropriate explanation for the emergence or expression of the short time scale behavioral adaptation of an organism. Note that the figure emphasizes the relationships between responses and reinforcers, stimuli and reinforcers, and stimuli and responses. The role of the organism in the figure is solely as a place holder or a context for the events.

A substantive treatment of contingencies on establishing and maintaining short time scale organismic adaptation are well beyond the scope of this text and are treated in other courses.

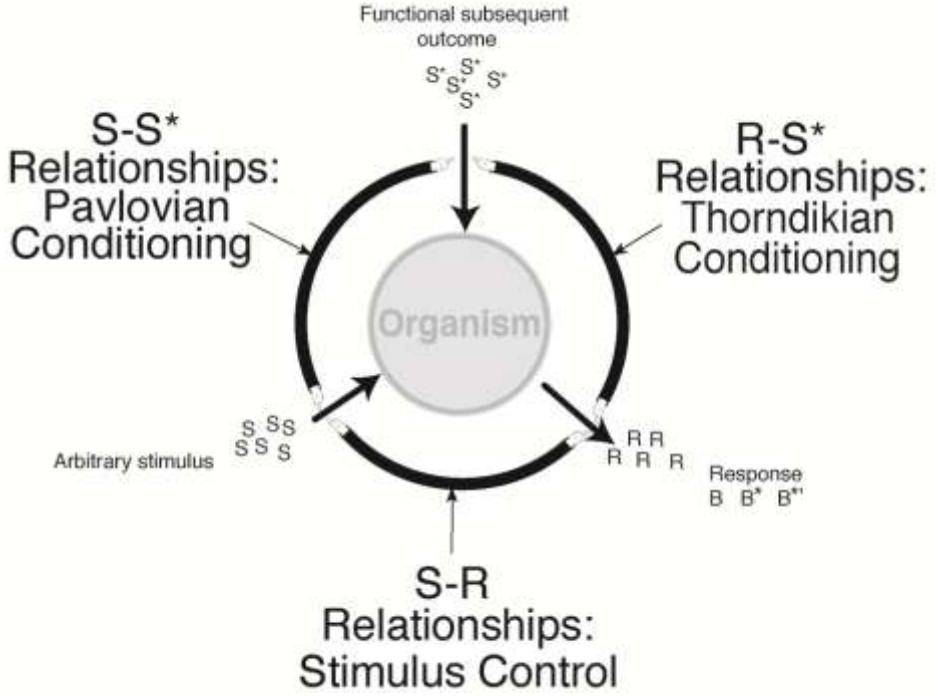

Figure 10.2 An illustration of an organism (gray circle) and three types of events: stimuli in the lower left, responses or behavior in the lower right, and reinforcers at the top. The functional relationships of interest in behavior analysis are: S-S (Pavlovian conditioning) noted in the upper left of the figure, R-S* (Thorndikian conditioning noted in the upper right of the figure), and S-R (stimulus control noted in the bottom of the figure). These elements are the necessary and sufficient elements to predict behavior from a behavior analytic perspective.*

The procedures that create or cause short time scale adaptation in individual organisms have traditionally been partitioned into two categories. One is labeled an RS* contingency or Thorndikian conditioning and the other is labeled an SS* contingency or Pavlovian conditioning. It is unlikely that either contingency could be implemented in isolation without instantiating the other, but for now they will be presented separately. These functional relationships illustrated in the upper

right and upper left quadrants of Figure 10.2 are the independent variables. The functional relationship illustrated in the lower quadrant of Figure 10.2 and labeled stimulus control is the dependent variable or result of the other two relationships.

From a behavior analytic perspective, virtually everything that makes an individual unique is the result of that organism's history of specific contingencies of reinforcement or schedules of Thorndikian reinforcement and schedules of Pavlovian reinforcement.

1. Functional Relationship 1: Response Reinforcer, or Thorndikian Contingency

RS* procedures cause the emergence of a stimulus response functional relationship (S-R) in an individual. These procedures have an event correlation and temporal correlation between the occurrence of a response and the occurrence of a functionally significant event such as food presentation. The emergence or change in the frequency of the behavior given a stimulus shows short time scale hysteresis and is typically labeled Thorndikian conditioning or operant conditioning. For example, if food presentation comes to follow key pecks, then the rate of key pecking will increase. Various classes of Thorndikian contingencies have orderly classes of effects. These effects show up as changes in the probability of a response given a stimulus or what is labeled stimulus control.

2. Functional Relationship 2: Stimulus Reinforcer, or Pavlovian Contingency

S-S* procedures cause the emergence of a stimulus response functional relationship (S-R) in an individual. These procedures have an event correlation and temporal correlation between the occurrence of a stimulus and the occurrence of a functionally significant event such as meat powder in the mouth. The emergence or change in the frequency in a behavior related to the unconditioned response to the reinforcer coming to occur to the antecedent neutral stimulus is typically labeled Pavlovian conditioning or respondent conditioning. For example, if meat powder follows a bell then the bell comes to control salivation similar to that controlled by meat powder in the mouth. Various classes of Pavlovian contingencies have orderly classes of effects. These effects show up as changes in the probability of a response given a stimulus or a change in stimulus control.

3. Functional Relationship 3: Stimulus Control

The S-R relationship describes the expression of a stimulus-response functional relationship in an individual. This third functional relationship is created by one of the first two fundamental relationships in short time scale adaptation. The result of Thordikian and Pavlovian conditioning is the creation or emergence of a new relationship between a stimulus and a behavior. That relationship emerges across a short time scale and is semi-permanent in that it

persists for a short time after the reinforcement contingency is removed.

D. Unit of Behavior

1. Conceptualization of Behavior in Terms of Common End State: Teleonomic or Functional Descriptions

An operant is typically defined as any behavior with a specific effect on the environment or end state. For example, a key peck is a key peck regardless of the precise topography of how the key is operated. It may be a fast head movement forward, a wing flap, a bite, or even a foot pressing into the key. This is the case because the object of research is to describe how the probability of the operant that immediately preceded the reinforcer changes across time. It doesn't matter what the operant was topologically, a head movement or a foot kick. It is whatever behavior immediately preceded the reinforcer.

These types of descriptions of behavior (i.e., teleonomic) are confused with teleological explanations because they reference end states, as do teleological explanations (and both terms start with the letter "T"). However, these functional descriptions do not posit a cause in the future; they simply specify a common end state. Consider a marble that is randomly rolled around in a frying pan with a hole in it. We can say "the marble will roll around until it falls through the hole." We are specifying an aspect of a variable series (how long it rolls around in each trial) as its temporal end point. In fact, we could predict that if we repeated the procedure of tipping the pan this way and that ten times, we would eventually get the same final result. Each time the marble will, sooner or later, fall through the hole. Note that we are not suggesting that the common end point in anyway causes the rolling around nor that the marble is trying to fall through the hole. Falling through the hole is a common final state of all the variable series and those variable series are under the control of simple totally mechanical factors, that are virtually random.

The use of the term "functional" for these descriptions that are based on a common end state arises from the fact that all the behaviors have the same functional end point such as falling through the hole, operating the key, opening the door, etc. From this perspective, repetitive head movements toward a key that don't quite operate the key are considered irrelevant because they are not the same behavior that operated the key and were followed by food. If the interest is how the behavior that was followed by food changes as the result of reinforcement, then ineffective pecks are something different and truly are irrelevant to the question at hand. Ineffective pecks cannot be counted. A functional definition of a behavior could also be a set of various unrelated behaviors that have no common physical effect (such as choosing five arbitrary behaviors and following any instance of any of the five with the same consequence).

Note that this usage of "functional description" is based on the usage of functional to mean what function does the behavior have as opposed to the usage of functional to mean how the *y*-axis measure changes in terms of changes in the *x*-axis measure. This behavior analytic usage is also different than the evolutionary biologists usage which is the evolutionary advantage provided by the

behavior. Carefully attending to the context in which the term “functional” is used will usually clarify its meaning.

2. Conceptualization of Behavior as an Act

Behavior can also be defined as some specific objectively measurable activity of an organism. In this case, the behavior is not defined in terms of its common end state such as opening a door, however accomplished, but rather by its actual measured topographical properties. Examples would include a forward head motion towards the key. For example, repetitive head movements toward a key that don’t quite operate the key are considered important because they are the same basic behaviors that operated the key (i.e., have substantial overlap with an actual peck on the key).

3. Conceptualization of Behavior as an Act “Related to the Unconditioned Response”

Pavlovian conditioning is not based on the selection of an arbitrary behavior and the subsequent modification of its rate by the contingency of some subsequent event such as food or shock. Rather in Pavlovian conditioning some behavior related to the behavior controlled by the unconditioned stimulus comes under the control of an arbitrary stimulus. Typically, the researcher selects a conveniently measured behavior out of the wide variety of potential behaviors expected to occur to the unconditioned stimulus. Any discrepancies between the CR and the UR are generally attributed to the differences between the CS and US. In salivary conditioning the dependent variable is very similar to the unconditioned response. Other preparations may result in a compensatory response to the CS rather than a UR like behavior. For example, when shock is used as the US, the CR is typically a compensatory or preparatory response rather than a behavior that strongly resembles the UR.

There are many questions surrounding the nature of the conditioned response in Pavlovian conditioning and how they can best be conceptualized. It is an active research area beyond the scope of the present text.

E. Assembly Level of the Explanatory Unit

The explanation of something that the organism does can be behavior analytically explained by appeal to relationships at different “assembly levels” or “sizes” or molarity of the behavioral unit. An example of this "assembly level" issue is exemplified by the interpretation of why a VI schedule and a VR schedule maintains different rates. The probability of individual short IRTs being reinforced (small size) or overall reinforcement rate across time as a function of the overall response rate (large size) would be the different assembly levels and are discussed below.

These assembly levels are often labeled as being more molecular or more molar, respectively. Be careful not to confuse molar or molecular when referring

to contingencies of reinforcement with level of molarity when referring to things such as cells versus organisms. To repeat, among other usages, sometimes molecular or molar refers to smaller or larger assembly levels in the same unit domain, and sometimes the terms are used to refer to higher or lower unit domains.

1. Molar or Relatively Large Explanatory Unit

In conceptualizing the rate in a VR schedule, we could appeal to functional relationships occurring in larger groupings or across longer temporal units. For example, we could appeal to the difference in the overall rate of reinforcement in a VR schedule when an overall higher or lower response rate occurs. A VR schedule results in higher reinforcement rates when higher response rates occur, whereas a VI schedule provides relatively equal reinforcement rates for virtually all response rates. A VR schedule would therefore, be expected to be ratcheted to higher and higher rates by higher reinforcement rates for higher response rates.

2. Molecular or Relatively Small Explanatory Unit

Alternatively, we could appeal to functional relationships occurring in smaller groupings or shorter time units in the VR schedule. For example, we could appeal to the small events occurring immediately before reinforcement to explain the higher rate maintained by a VR schedule than by a VI schedule. It could be argued that on a VR schedule, it is more likely that reinforcement follows a later response in a burst of responses than following an isolated single response because the probability of reinforcement increases as more responses occur. As a result, if bursts of closely spaced responses occur, then a response quickly following the previous response it is more likely to be reinforced in a VR schedule than in a VI schedule. According to this view, the resulting greater rate of bursting in a VR schedule is therefore responsible for the higher overall response rate in a VR schedule.

F. Exclusive Focus on External Functional Relationships

Recall that a behavior analytic explanation is entirely externalistic.

1. The Mind/Body Quagmire

a. Not "Biological as Opposed to Psychological" (i.e., Body vs. Behavior)

This inappropriate conceptualization is sometimes articulated as "is that a biological change or a psychological change?" It cannot be suggested that biological changes such as a change in a neuron involve a change in some constituent or process in the body while psychological processes such as learning to peck a key do not involve biological changes. Psychological changes that do not involve the

body would imply that those changes exist outside the natural world. If those changes were associated with a specific organism, then they would presumably be at the internal locus labeled "the mind" – an unnatural entity.

Behavior analytic explanations are functional relationships between environmental events, and are independent of any biological mediators. But even so, there is no evidence whatsoever that there is actually some process in addition to the biological process.

b. Exclusive Focus on Behavior, Body is Irrelevant

It is inappropriate to suggest that the proper explanation for behavior is by appeal to the body because behavior changes involve the body. If the argument is that internalism is the most acceptable explanatory path, then explanations cannot stop at biology, but rather must proceed all the way down to quantum mechanics. Clearly all behavior changes ultimately involve changes in the strong and weak force, the electromagnetic force, and gravity. However, it should be obvious that it is of little practical help to discuss the cause of behavior change in terms of either quantum mechanics or biology.

We are psychologists; we are neither biologists, chemists, nor physicists, and therefore we study behavior with respect to its controlling variables **as opposed to** studying the organism (or the body). The appropriate explanation for behavior is by appeal to relationships in the environment (i.e., an external explanation).

2. Intervening Variable / Hypothetical Construct Slippery Slope Trap

Unfortunately, the simple specification of the functional relationship (i.e., mathematical or logical relationship) between independent and dependent variables often devolves into some physical or quasi-physical internal model. What is at first a functional description entirely between external events, becomes: 1) a handy internal process not presumed to be real, and eventually, 2) an actual internal process presumed to be a step between input and output. (McCorquodale and Meehl (1948) label the penultimate processes (i.e., 1) intervening variables: and the latter processes (i.e., 2) hypothetical construct; while Hull (19xx) labeled them hypothetical and intervening variables, respectively (i.e., the reverse). McCorquodale and Meehl's usage is the most popular even though Hull's usage would seem more consistent with typical English usage and avoids the necessity of using definitions such as "an intervening variable is a purely hypothetical entity while a hypothetical variable is one that actually physically intervenes between the input and the output.

From a behavior analytic perspective, it doesn't matter a whole lot how intervening variables and hypothetical constructs are defined, in either case the referents are of little use.

G. Conceptual Follow-up: Behavior Analytic Externalistic, Functional Conceptualization of Causation and Explanation, and the Passing Over in Silence the Unproven or the Unprovable

An unfortunate outcome of the demand for an empirical subject matter by behavior analysis is that the point can be misunderstood more easily than correctly implemented. Too many people anxious to avail themselves of the prestige of a rigorous scientific position believe that the task of science in general and behavior analysis in particular is to adamantly deny the existence of anything that sounds soft minded such as a private event, or that is typically conceptualized as a mental process such as "a personality." Otherwise, they would be a shallow, dilettante psychologist.

This incorrect approach of presuming anything sounding soft-minded is to be vehemently and categorically denied out of hand (as opposed to reframing the issue) can lead its proponents to fatuous assertions such as, someone cannot have a toothache because the pain of someone else's toothache is not an objectively measurable event, or that no one can have a personality because it is a non-empirical thing that is inside the organism and there is no conscious entity within an organism that could be following the rules specified by "the personality."

Alternatively, the incorrect understanding of radical behaviorism can lead proponents who don't really understand it to desperately try to change the course of the discussion when toothaches or personalities come up because they don't believe there is a good answer to that challenge because everyone has had a toothache, and we can predict the behavior of our friends in many situations because everyone has enduring characteristic ways of responding or what could be labeled a personality.

Behavior analysis does not assert that internal toothaches and internal personalities do not exist. Rather, behavior analysis reframes the issue to the facts at hand rather than becoming ensnared in inferences which may or may not be veridical. There are external behaviors associated with toothaches and personalities. In point of fact, the external behaviors gave rise to the internal inferences (not the other way around).

The simple answer to these types of issues is that behavior analysis is exclusively focused on external objectively demonstrable events. All other issues are considered irrelevant. We have at hand a person screaming about a toothache: what can we do about it? Alternatively, we have a person reliably exhibiting a set of behaviors: what is so strange about that?

The task of behavior analysis is not to prove nor to assert the non-existence of the personal experience of a toothache (or anything that cannot in principle have direct external empirical and consensual support), rather, the task of behavior analysis is to remain focused on the facts of the issue being discussed: i.e., a functional analysis of an individual's behavior with respect to the environment in time. Neither issue requires dealing with inferred internal entities. It is an inarguable fact that the person is yelling in pain and people have patterns of behavior. The fact is, the functional relationships among external events are all that anyone involved on either side of the argument has anyhow.

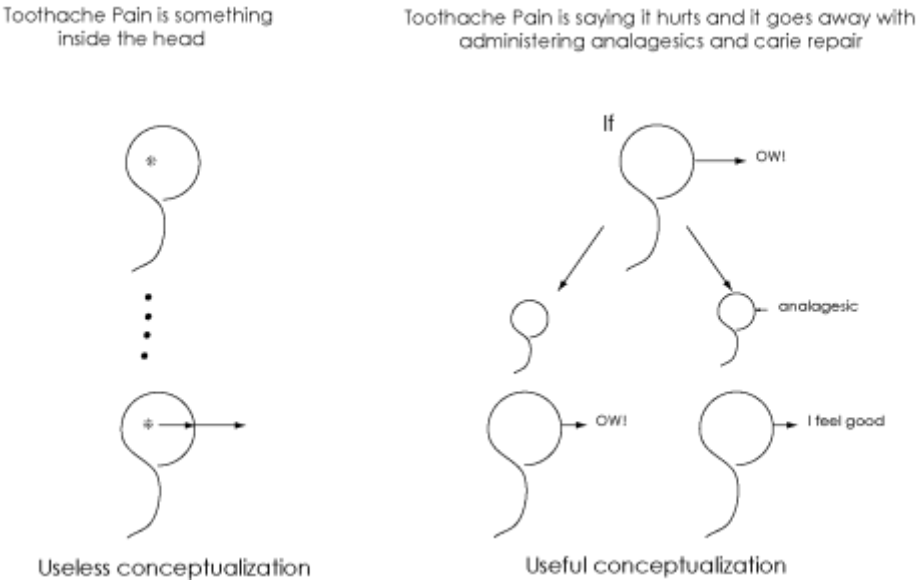

Figure 10.3 The left portion of the figure illustrates a common conceptualization of something like the pain of a toothache by the lay public with an asterisk, i.e., it is something inside the head. The right portion of the figure illustrates the behavior analytic conceptualization of what we know of toothache pain. Behavior analysis passes over in silence anything that may or may not be inside the organism.

Figure 10.3 portrays an example of the types of facts in any discussion about someone's subjective experience of toothache pain in the right portion of the figure, and the meaningless inference about internal states or entities based on those facts in the left portion of the figure.

It is not that it has been proven that the person does not experience pain, rather the indisputable facts are: 1) discussions pertaining to private events can be no more than inferences based on objective public behavior and 2) nothing that could be said about the private aspects of private events can be proven nor can it be falsified. It is therefore pointless to argue about them. In that sense, private events are meaningless concepts. Skinner correctly identified the only thing that can be said about private behaviors: in the absence of contravening proof, it is reasonable to presume that private behaviors have all the same functional properties that public behaviors have. For example, if those private behaviors are reinforced on a fixed-interval schedule, they will exhibit a low initial rate and will increase in rate as the time of reinforcer availability approaches. However, as he also pointed out, that was only his unproven and unprovable guess, even if it is eminently plausible.

Radical behaviorism is the position that asserts that cause, meaning, and explanation come into existence by way of the external empirical functional relationships involved (such as saying ow and holding one's jaw) rather than from conjecture about non-empirical internal inferences. Arguments about internal private events are avoided by behavior analysts because such arguments are, in principle, unresolvable and therefore meaningless. Becoming embroiled in an argument about internalisms is also impractical because nothing can be gained by that argument.

It is crucial to understand that the repair of tooth decay or the administration

of analgesics are external objective events that have an effect on the external objective behavior of screaming "I am in pain." They are not proof concerning the mental representation of pain.

A verbal muddle that is occasionally advanced to illustrate the weakness of a behavior analytic view actually illustrates the opposite: its strength (i.e., that a behavior analytic perspective and its total rejection of sophomoric controversy is both pragmatic and philosophically sound). The sophistic argument proceeds as follows: suppose someone is told the combination to a box that will be available to them in one hour is 37 and that the box contains one hundred dollars. The question is: immediately after being told the information, before any behavior could occur, did that person learn anything? The point of the sophism is thought to illustrate evidence of learning in the absence of any response (latent learning) and to illustrate the difference between learning and performance. A behavior analyst would simply say that until some behavior (such as successfully opening the box) occurs, the question is meaningless for three reasons. First the definition of learning is a behavior change resulting from some exposure. Absent a behavior change, the term "learning" is inappropriate. For instance, before you add the hydrogen to oxygen, you cannot argue that the oxygen is water. Second, in the absence of a behavior which proves that learning occurred or not, you cannot prove or falsify one side or the other, making any discussion of the issue unresolvable and therefore meaningless. This point should be self-evident to anyone who ever got a test question wrong in school. Just because you read the book does not make all your answers correct. Reality is not determined by your wish or hope. Third, it could be argued (fruitlessly) that knowing that they had the exposure to the answer, you could ask them to tell you the number, and then when the safe appeared you could try that number they told you. If it worked, then you could say that they had learned something when first told the combination. Reread the last four lines of text. What two <u>behaviors</u> were essential? 1) They <u>told</u> you a number, and 2) when the safe was available the combination <u>worked</u>. Fourth, it would be pointless at best to argue that after the behavior occurs, one could then infer that learning had occurred in the past in that individual immediately after 37 had been given to them - why would anyone care? What productive use could be put to that post hoc information? It's not guaranteed to be true in the next individual, nor in the same person if you did a new test.

Revisiting the SIRDS example, we have another excellent example of what we really know and what can be known (i.e., the radical behaviorism perspective) vs. what may be interesting hypotheses or beliefs but that are nevertheless nothing more than guesses or hopes. When someone looks at the dolphin SIRDS and after some time, says "Oh wow! I see a dolphin floating in the air. It is pointed to the left and …… and ……" after which we would say "they see the dolphin." The point of this anecdote is to reveal what is the actual referent for our saying "they see the dolphin." It is **not** some activity in their mind or electrochemical activity in a piece of meat in their head that we are observing . Rather the term "seeing" is the way we summarize a set of **external behaviors,** like trying to reach out to an object that is not there, and saying the words they said, or them telling us other elements in the SIRDS. We have only external behavior to base our referent of their "seeing"

upon. We do not have any empirical evidence of anything inside their head and neither do the people who argue for explanations based on the mind. In principle, it could be space aliens channeling information.

A thought experiment brings further clarity to the issue of whether private events are actually private events that we have special arcane knowledge of, **or** rather are our inferences based on public behavior. The next time a discussion of a private event comes up, before getting uselessly embroiled in the discussion, imagine that the person having the private event about which the discussion revolves had been in an isolation room for months on the moon such that no one could detect any behavior whatsoever from them. Exactly what would either of the discussants use as evidence for the existence of the private event? In the absence of evidence, it would be obvious to even a mentalist that the discussion would be limited to the fantasies of the people having the argument about the properties of the private event. It would be no different than two drug filled psychotics arguing about the hats the surrounding leprechauns were wearing.

To make the thought experiment even more compelling, imagine it was you in the isolation room and you were thinking (a private event) about riding a bike while the two hapless sophomoric philosophers were arguing about whether you were thinking about cooking or thinking about fishing. How would you let them know they were wrong? How could they get it right? Who could come to your defense and prove them wrong? What evidence would they use?

To recap the point of the discussion about private events: it is not the case that we know the inferred private event is not true or that it does or does not exist. Rather, getting embroiled in an argument about private events serves no point. it is meaningless. In Skinner's words "it is not pragmatic".

H. Conceptual Follow-up: Useful Grammar for Productively Conceptualizing the Behavior of Organisms

Our task of understanding behavior is made more difficult by our language tradition, which typically describes things with the subject of the sentence being the animal (the doer) rather than the behavior of the animal (Bacons' idols of the market place). For example, we typically, but wrongly, say we like or dislike a person. We rarely say we like or dislike the behavior of that person. People often wrongly talk about reinforcing or punishing the person rather than reinforcing or punishing the behavior. The following principles take us a long way toward paying attention to the actual controlling variables of behavior. It is how we could keep from being betrayed by our words and our grammar.

1. Avoid Reference to the Animal

Because we are interested in behavior rather than the animal, a useful heuristic rule is to avoid reference to the animal whenever the context is clear. **This does not mean simply using the word "subject" rather than the word "pigeon."**

We are interested in movement, not the thing that moves. Focusing on the organism can lead us down blind alleys. If you avoid references to the animal, you must then focus on behavior which is precisely the point of this heuristic. For example, the construction "when a peck occurred it was followed by food presentation" forces attention to what is actually happening. The inferior construction "when the bird pecked, food was presented" can lead one to think that the bird was reinforced and that can lead to the tautology that the bird was the source of control over its own behavior and the experimenter becoming focused on what the mind of the bird learned as the result of the contingency (e.g., what did the bird learn from the contingency?).

Note the subtle shift from the natural world to problems of our own manufacture in the following series of "descriptions" of the same event.

- A key peck occurred when the light came on.
- The pigeon pecked the key when the light came on.
- The pigeon learned to peck the key when the light was on.
- The pigeon learned to peck the key in order to get the food when the light was on.

- The pigeon learned the rule "key pecks produce food when the light is on."
- In order to get the food, the pigeon learned to use the rule "key peck produces food when the light is on" whenever the light came on.
- In order to get the food, the pigeon came to understand the meta-rule causation.
- and on and on ...

If the environment or the behavior is the subject of the sentence, that is where you and your readers put their attention and that in turn makes it simple to understand events in terms of their actual causes.

In this regard, it is interesting to note that when other people do something bad, we tend to attribute it to the person or an internal cause. When we ourselves do something bad, we tend to give the environmental influences as causes. The reverse is true when the behavior is good. Others do good because the environment caused it; when we do something good, it's because we are good. A wag could thereby point out that people may be ignorant about the determinants of our good or other's bad behavior, but they are pretty insightful when it comes to understanding the determinants of their own bad or other's good behavior.

2. Avoid the Active Voice with Respect to the Animal

A second useful "heuristic grammar" is to not use the organism in the active voice when you must refer to the animal. If the "pigeon" is passive, then it is much easier to maintain our focus on the actual controlling variables, rather than to tautologically imply that the pigeon is the explanation for its own behavior. For example, "following 30 days of exposure to FR contingencies, the responding occurred within 2 seconds of the trial onset in the pigeon, while responding

occurred within 8 seconds of the trial onset in the rat." In this case, the independent and dependent variables are obvious. On the other hand, with the inferior construction "the pigeon responded within 2 seconds of the trial onset while the rat responded within 8 seconds of the trial onset following 30 days of exposure to FR contingencies," we are led to look inside the animal's head for the explanation for the behavior.

A second problem with the animal in the active voice is that you can be led into believing things that are simply not true. For example, it is a fact, when you say "the pigeon was exposed to the red light." You really don't know any more than that. To say "the pigeon saw the red light" or "the pigeon understood what to do when the red light came on" is not necessarily true and you have no business asserting it.

Putting causes into the pigeon that you simply make up leads to an infinite range of meaningless pseudoexplanations. For example, if the pigeon did not peck the key when the light came on, is that because the pigeon:

- did not notice the light
- failed to encode the information
- failed to retrieve the information
- failed to use the information
- failed to want to decode the information
- failed to understand which strategy to use
- actively wanted to encode the information incorrectly
- was being passive/aggressive
- had a need to fail
- etc.

The point being that the contingencies control behavior. The pigeon does not do anything. **The pigeon is not the causal agent. It cannot be the causal agent. That would be saying the the pigeon pecked because the pigeon pecked**. Our task is not to discover how the pigeon did it – our task is to discover how the environment did it. Alternatively stated, our task is not to discover how the mind made the pigeon peck, but rather our task is to discover how the environment made the mind make the pigeon peck (which, of course, reduces down to how the environment made the pigeon peck).

To wrap up these heuristic grammars, it is informative to stop for a moment to recall that your task is to understand behavior and to make empirical, falsifiable, and meaningful predictions about behavior, not to generate eloquent sounding stories.

Stated in a less gracious form, your task is to prove yourself smart and your subject stupid, not the other way around.

II. Conceptual Contrasts Between Behavioral and Other Explanatory Approaches

A. Internal Empirical (Biological) Versus External Empirical (Behavioral) Explanations

The difference between behavioral (external) and internal views is fundamental: past the skin and you are a biologist or a philosopher, not a behavior analyst. The following anecdote illustrates the different interests different people can have in how a system works. Suppose that after wandering around in a desert for a few days with no water, you come upon an entirely unknown water dispenser. Not knowing how it works, you phone the manufacturer and ask, "What makes the water come out?" The manufacturer answers, "When the can release cog is actuated into the release mode by the activation wheel." Because you are nearly dying of thirst, you then rasp, "What turns the activation wheel?" He then answers, "The activation wheel motor." You then, a bit less politely ask, "What makes the activation wheel motor turn?" The engineer unflappably responds: "The activation wheel motor transistor enabling circuit." After a seemingly interminable delay of being educated about the internal workings of the machine, how those parts were made, where they were purchased, what color they were, and how they were assembled, and how they changed over the various model years, you would scream that you were a behavior analyst and you wanted to understand how to control the behavior of the machine, not manufacture one. The manufacturer would undoubtedly raise his eyebrows and condescendingly quip, "Well, if you must know the brute input/output answer. You turn on the power, while pressing the yellow button, and then press the emergency delivery code which is 3397." The point of the anecdote is that what makes a water dispenser, or a living organism behave is best seen to be in the environment not on the inside.

As a different example of how behavior analysts deal with environments and behaviors rather than internal entities: if a TV picture isn't exactly what you want, you usually give it a signal with the remote control to change the channel. You don't open up the back of the TV and start changing transistors and ripping out wires. TV sets have evolved just as biological organisms have. Adjustments that have to be made often and locally are under the control of signals in the environment sent by the viewer. Channels can be changed, the volume can be raised or lowered, and so on. Ultimately, of course, all those things are in fact mediated internally by circuitry, but this is not typically what we mean when we ask: "How do I change channels." From the practical perspective, what causes the channels to be changed is pushing the green buttons on the remote control, not changes in the inductance of an internal circuit.

The same goes for life forms and their behavior. They, too, have evolved. The adjustments that need to be made often and locally are under the control of signals in the environment. Organisms learn as the result of nonrandom relationships in the environment. Ultimately, of course, all those things are mediated internally by the biology, chemistry, and quantum mechanics of the organism, but this is not

typically what we mean when we ask: "How do I change that organism's behavior", or "what caused the behavior to be changed." The answer we want is what are the changes in the environment that will lead to the new equilibrium, not what changes in neuronal or quantal activity will lead to the new equilibrium. In the vast vast majority of cases, we have no way of directly changing the activity of neuronal circuits other than environmental manipulations anyhow. When the answer to how do we make the organism behave is given as an internal process, we were not given much to go on. The task would simply change to how to make the internal process cause the behavior we wanted to produce.

The conceptual difference between internal and external approaches to changing a TV channel is analogous to the difference between biology and psychology's approach to behavior. The difference between the internal model (medical model) and the external model (behavioral model) as an explanation for psychological problems is metaphorically the difference between seeing behavior as "transistors incorrectly biased" versus "knobs set wrong." Medical people change the bias on transistors by adding or subtracting resistors to the circuit board's transistors (drugs and lobotomy); psychologists turn knobs (adjust environmental contingencies).

An example of the enormous difference in the practical usefulness of an external approach over an internal approach can also be seen in the task of being responsible for helping someone develop muscles. Muscles are obviously of biological substance and are made up of cells. The revealing question is: what types of knowledge and what approach will be most productive in helping you accomplish your job of helping someone develop muscles in the least invasive manner (e.g., steroid damage), biology or psychology? The fact is that it is your ability to provide reinforcers for the lifting of weights by the other person that matters most in helping someone develop muscles, not your or their understanding of the cellular or chemical or quantal structure of muscles. When considering the issue of the difference between people with or without muscles, or how a person gains or loses muscles, muscles are best seen as the result of environmental experiences, not cell growth. The value of an environmental approach to something as biological as muscles reveals the importance of an environmental approach for issues such as learning to play the piano, personality, attitude, and any other aspect of psychology.

B. Internal Non-Empirical (Mentalistic) Versus External Empirical (Behavioral) Explanations

A mentalistic explanation simply gives some internal entity all the input, decision, and output capacity necessary to accomplish whatever is needed to make the undiscerning reader stop asking questions. Mentalistic explanations are at best a tautology.

The difference between a behavioral and a mentalistic explanatory strategy is that the behavior analytic paradigm is unwilling to be satisfied with a useless answer. The difference between a mentalistic and a cognitive explanation is that cognitive explanations try to evaluate what may be a ramification of that

explanation.

A frequently invoked internal metaphor for how an organism comes to behave correctly is a telephone switchboard (the brain) and an operator (the mind). For example, a stimulus is presented to the organism. It is said to travel to the switchboard where the switchboard operator (mind) evaluates the stimulus, decides on an appropriate course of action and activates the appropriate effectors on the output side of the switchboard.

This metaphor brings great comfort to many students of psychology. For example, in order to explain how an actual telephone operator at the phone company functions, we could say that the operator (outer) receives a stimulus from the switchboard (outer). This stimulus is sent to the switchboard (inner brain), where the operator (inner mind) decides what to do and activates the proper switchboard output (inner brain) that causes the operator (outer) to activate the proper switchboard output.

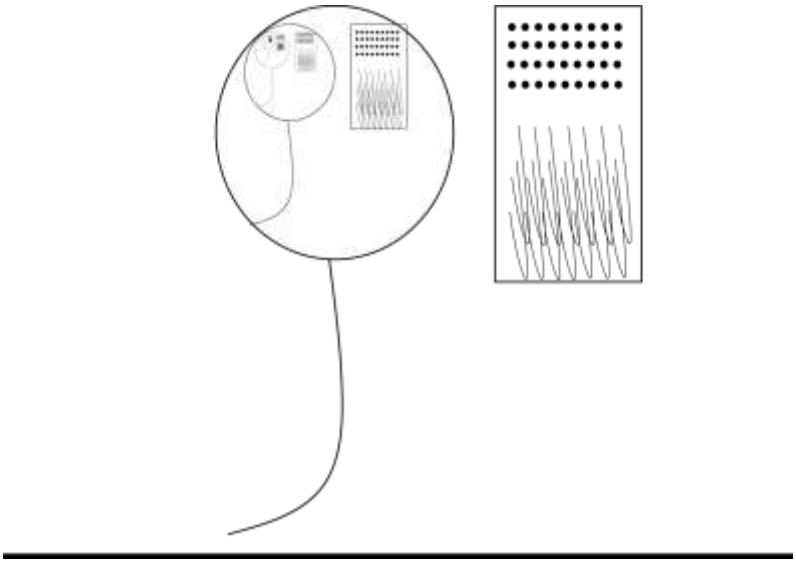

Figure 10.4 An illustration of a 1920s telephone switchboard operator being controlled by an internal telephone switchboard operator, being controlled by an internal telephone switchboard operator, being controlled .....

To argue that an actual operator knows what to do because an internal operator knows what to do reveals how empty and preposterous the mind is as an explanation. Similarly, to argue that a rat learns a maze because a human telephone operator in the rat's head looks at a cognitive map, or to argue that a child behaves similarly on several tasks because a telephone operator in the child's head looks up a rule in a rulebook is silly. That type of internal "explanation" is tautological. The power of a telephone operator explanation to account for baffling empirical findings is an illusion. How does the inner mental telephone operator work .... an even smaller submental telephone operator? Simply passing the problem on rather than solving it is much like saying Shakespeare's writings are too good for him to have written therefore someone else must have written them; or that life on earth couldn't have evolved, therefore life on earth must have come

from some other planet. An astute person would ask how did the person who actually wrote Shakespeare get so smart? Someone else? How did life on the source planet get started? From yet another planet?

A critical point of focus in evaluating any theory, therefore, is the degree to which it invokes some unknown decision-making process within the organism to decide what to do (e.g., the inner operator **telling** the outer operator what to do; the child **using** a rule to decide which alternative to select; the rat retrospectively **evaluating** the correlation, etc.). To the degree that the behavior of an inner entity decides the behavior of the outer organism, the explanation is empty, and in fact, should be seen as foolish. The subject of the verbs "tell", "use", and "evaluate" would have to be as complex as the organism trying to be explained.

The trap is that a mentalistic explanation will always, on the surface, **appear** to make sense out of the behavior of the subject and therefore will always **appear** to be a better explanation than a behavioral explanation to an uncritical thinker. This is because the inner operator is always magically given whatever knowledge and power is necessary to get the outer operator to do whatever it in fact did, right or wrong; whereas a behaviorist must actually find out an empirical explanation for why behavior occurred the way it did. An internal entity that chooses to do what is optimal sounds like a plausible cause until the person (whose behavior you are trying to explain) is smoking a cigarette while the mind of that person tells you "I wish I could quit." What is causing the smoking if the mind doesn't want to smoke? It would have to be a mind within the mind or a subconscious; the regress is infinite, and not even funny, it's sad.

C. Internal Non-Empirical (Cognitive) Versus External Empirical (Behavioral) Explanations

The difference between a mentalistic and a cognitive explanation is that mentalistic explanations simply make up something that sounds good to unsophisticated listeners. A cognitive explanation on the other hand attempts to evaluate what may be ramifications of that hypothesized explanation. Both mentalistic and cognitive explanations believe that an internal cause is useful in explaining behavior.

The entire issue regarding the use of internal versus external explanations is brought into sharp focus with the principle "smart animals prove the experimenter stupid while stupid animals prove the experimenter smart." To reiterate what this principle means is that we as professionals must know what causes behavior, not simply come up with impressive names for it. For example, we could presume that the herring gull was smart because it knows that it must retrieve its eggs when they get bumped from the nest in order to keep them from dying and in order to preserve the species. We could give the bird any number of complex realizations, processing centers, or divine inspirations. We could try to impress our colleagues by showing how smart the birds were because they knew to retrieve their eggs.

However, an alternative approach to discovering why something happens is to understand how a behavior varies as a function of various experiences in order to

understand the entire set of functional relationships pertaining to that behavior (i.e., a functional analysis). Rather than endlessly searching for the unattainable metaphysical internal "why", the empirical "why" can actually be discovered. Relatively straightforward research (a functional analysis) which varied the color, speckle pattern, and size of artificial eggs showed that eggs were retrieved in the order green > yellow > brown > blue; more speckles > less speckles; and large > medium > small. This showed that stimulus conditions governed egg retrieval and that some unnatural stimuli worked better than natural stimuli (the gull eggs were, in fact, brown, moderately speckled and a medium size).

Similarly, a snail could be said to be smart because it knows to climb to the top of a tree in order to get to the most tender leaves. A theorist searching for an internal non-empirical explanation could give the snail a good-nutrition-processing center that was inhibited or released from inhibition by various decision rules. However, research has shown that the snail moves so that its shell pulls "back" (i.e., negative geotropism).A herring gull can be made to retrieve very large pieces of green highly specked wood more than its own eggs, and a snail can be guided toward the worst leaves or even a frying pan with garlic butter by pulling on its shell. Both of these resulting behaviors are inappropriate and in fact are very destructive to the individual and species.

Simply put, animals do things because of environmental causes not because of optimization or internal decision-making centers. Doing things under the completely predictable control of some external conditions like pupillary contraction to light or knee jerk to patellar tap is often considered stupid because its control is as predictable as a light going on when the switch is flipped. If you know the environmental causes: 1) you can make the animal do something "stupid" (completely determined and predictable) by controlling those causes, and 2) you can prove that you understand the psychological process controlling the behavior.

The Renaissance provides an exceptionally clear example of the importance of understanding empirical external causes of behavior and the vacuousness of even the most impressive sounding internal causation. Human beings react correctly to distance in the environment. They can throw an object to correctly land in a box placed 5 or 50 feet away. They can say: "that thing is far away, this thing is close." Before the Renaissance, the "knowledge" of distance was an internal intelligent wondrous skill humans had. Humans reacted correctly to distance because they were smart. They had a depth realization center in their brain.

A little functional research showed that "perspective" or the convergence of parallel lines in the distance made humans say "that thing is far away, this thing is close" even though both things were equidistant. Humans were shown to be simply under the control of environmental stimuli (i.e., humans were shown to be "stupid"). The discovery of the environmental determinants of distance or depth perception (apparent convergence of parallel lines) in Florence in the early 1400s proved Alberti brilliant and changed the art world forever.

The events in the environment which control different behaviors as a function of their changes are what we mean when we ask for an explanation of how or why we see depth, and those details are what we want when we want to know how to

paint a painting or make a two-dimensional movie appear to be three-dimensional. In the previous metaphors, we want to know how to get water out of the machine or how to change the channel of the TV or how to get a snail to turn right by changes in the environment not via postulated internal events unconnected to the environment that leaves us powerless to help, control, or understand behavior. When we have a practical problem to solve, the cognitive processing center of a homunculus is a useless tautology. We want to know the factors that change behavior. A behaviorist would argue that explaining how the outer animal behaves with the use of an internal processing center is simply explaining on "credit." The real explanation is simply put off for another day and will eventually have to be paid in full with interest. Spending explanatory capital that you do not have requires that you then focus your effort on paying back your debt.

III. Models as Explanations

A model is a formalized explicit system that can be used to predict behavior. It should be recalled at this point that the value of a model as an explanation is only as good as its empirical support in spite of its other attributes. Models vary from the simple specification of the common functional relationships in multiple data sets such as Weber's Fraction, to very complete systems of prediction and explanation applicable to a very broad range of phenomena in a wide variety of contexts such as the matching law. Note that to be behavior analytical, a model must be verifiable, must specify functional relationships, and be completely externalistic. **Behavior analytic models specify how outputs are related to inputs, NOT how some internal process makes that relationship happen**.

In the simplest, a stick could be used to model a piece of pipe. When you push one end of a stick, the free end moves forward. When you pull the stick, then the free end moves back. The behavior of the stick provides a good model of what the piece of pipe will do given the same inputs. Alternatively, the mathematical function "output = (2 * input)" correctly models an amplifier with the gain set to 2 so that each input signal comes out twice as loud.

The value of a model is that it can predict what will happen in the target as the result of various inputs. Better models predict what will happen in the target across a wider range of independent variables, have wide generality, or predict in more contexts, and require fewer free parameters. Additionally, models that are simpler (e.g., $e = mc^2$) or easier to use (e.g., output = (2 * input)) are preferred.

A model can best be seen as having two components. First is the machinery that produces the prediction (semantics), and second are the rules governing the application of the model to the target (syntax).

Additionally, models must correctly specify when they are expected to apply and precisely how they apply. For example, a stick will not predict what happens when water is applied to one end of a pipe, and output = (2 * input) does not predict the volume output of an amplifier when the input is below threshold or is set high

enough to cause clipping.

The strength of models is also their weakness. Models allow us to easily infer functional relationships that would be unexpected without the model. When those inferences are right, we jump ahead; unfortunately, when they are wrong, our conceptual inertia could force empirical data into a model that does not work and thereby we could become lost in a maze of dead ends of our own making.

A second problematic aspect of models is that the logic of their interpretation could be faulty. Most tests of models rely on affirming the consequences, for example, some model could suggest that the moon is made of green cheese. Green cheese has a bubbly surface. The moon has a bubbly surface, therefore someone could conclude that the moon is made of green cheese. A second example is given in the "why geese retrieve eggs" anecdote. The cognitive neuroscientist's model was supported by results but could have supported hundreds of different models, and the model provided no information that we did not already know.

IV. Conceptual Review

A. Principles of Behavior Analysis

1. Behavior Analysis is a Deterministic and Principled Science

With respect to its methodology, resulting knowledge, and explanatory system, Behavior Analysis is based exclusively on events in the natural world and is unreservedly committed to the view that all behavior is the result of a specifiable cause. Behavior analysis is deterministic. Behavior analytic explanations do not provide for divine intervention, free will, magic, or space alien control.

Additionally, behavior analysis, like any science is based on the realization that the enormous variety of phenomena in the field are the result of a limited number of fundamental processes interacting in a limited number of possible ways. Those processes and interactions have non-random results and those results follow specifiable rules. The view is that causation is reliable and that Euclidian like logic can be used to advance our understanding from fundamental research findings to statements of general principles of causation and expected results. This type of principled system enables research to produce transitive knowledge which cumulates with each additional research finding.

As a principled science, behavior analysis first reduces the broadest possible set of behaviors to a minimum number of empirical externalistic processes (such as reinforcement and stimulus control). Those processes have defined properties and functional relationships. These systematic processes or principles are used to explain behaviors in the natural world, and to create a principled system with which to generalize or predict and under what conditions those behaviors will occur in the future.

In order to be meaningful, there cannot be any discrepancy between the occurrence of events in nature and principles. If there is a discrepancy either the event was misinterpreted or the principle is in error. If a principle is in error in one case, then its explanatory power is questioned in any application. To a

principled science any discrepancy is of grave concern and the rationale underlying most research. To an unprincipled science (an oxymoron) a discrepancy between its processes and an event in nature is of no real concern, because principles can be eclectically and indiscriminately invoked as necessary for each different question even if they are contradictory.

2. Behavior Analysis Requires Objectively Demonstrated Entities and is Therefore Strictly Externalistic

For the same reason that a judicial system must move away from convictions based on the intuition of the prosecuting attorney to decisions based only on provable facts; so too must any system of psychology move away from the intuitions of its practitioners to decisions based only on proven facts. The goal of a judicial system or science is to entirely remove personal opinions and intuitions from the decision process. Only in this way can the field be practicable, only in this way can the field be sure of always moving toward the truth, and only in this way can the field be ethical.

If something is not known to be true, it is excluded from the knowledge base. It's rather like wanting to be sure that a jug of water is not contaminated before pouring it into the cistern containing your only drinking water. Additionally, meaningful communication requires that the speaker and the listener necessarily have the same referent for the communication. Finally, if a disagreement or miscommunication occurs, then there must be a procedure for resolving the issue by way of a publicly available and failsafe procedure that inevitably results in a resolution that both sides would have to accept if the discrepant views cannot be resolved then neither can be considered a fact.

A serious impediment to progress in traditional Psychology has been the use of causal variables hidden inside organisms where they cannot be proven true or false and had to be accepted as is. As a result, facts were contaminated with opinions and psychology became less than what it could have been. For example, a Freudian could be asked to explain why a person smokes when that person says that they wish they could quit. Presumably the thing that is causing the person to talk (the mind) is the same thing that causes the person to smoke (the mind). The Freudian would simply retort that that proves the existence of an invisible subconscious inside the mind in order to justify the discrepancy between behavior and its putative control (the mind). Presumably if it could be shown that the subconscious also wanted to quit, the Freudian would simply say "oh wow, we have just discovered that humans have a sub-subconscious." Behavior analysis builds only on external objectively provable entities and eschews the creation of ad hoc explanatory actions, because things are not true simply because someone wants them to be true.

Even if internal entities are proven true, Behavior Analysis does not consider internal explanations as the explanatory high ground. Rather explanations which specify external processes which control or predict behavior are considered the necessary and sufficient foundation for understanding behavior. For example: suppose you touch one end of a single neuron organism,

which in turn activates the dendrite within, which in turn activates the axon, which in turn actives the muscle, which in turn moves the organism. From a behavior analytic perspective, "touching the organism made the organism move" is the specification of the process that made the organism move. It is a sufficient and useful explanation because the relationship between the controllable environment and the measurable behavior of the organism is understood while "the neuron made the organism move" is neither a necessary nor a sufficient explanation because it tells you nothing about the functional relationship between the controllable environment and the measurable behavior of the organism. "The neuron made the organism move" gives you nothing that would allow you to get the organism to move. "The neuron made the organism move" is in that sense useless information unless you are a biologist and are only interested in cell activity per se rather than how that cell activity came to be or what the final organismic output of that cell activity was. Behavior Analysis is about the behavior of the organism.

3. Behavior Analysis Establishes Explanations, Causes, and Meaning Via the Functional Properties of Objectively Demonstrated Entities

The most definitive aspect of the meaning of a thing is contained in the complete set of all observable functional relationships between it and the natural world.

For example, a smart phone, at one level is clearly an empirical physical object about 6 inches by 4 inches by ¼ inch, made of metal and plastic with one surface made of glass. From an internalistic perspective, it is an empirical central processing unit, with a graphical processor, memory, and input sensors and output actuators. However, the most important and defining property of a smart phone is the empirical functional properties of its user interface. If you push "this" button, the phone turns on; if you touch "this" spot on the screen, a menu is displayed. Swiping the screen reveals additional options. Touching the blue spot displays a picture of you and a friend in Cancun. Sliding your fingers apart allows you to show the scorpion on the ground next to your foot just before it stung you. Additional higher-order functional relationships provided by the phone allow you to set your personal preferences for your user interface thus giving your phone its own enduring characteristics of behaving to the inputs you give it (i.e., in that sense the phone can "learn" to have its own "personality.") Even memory capacity and speed are only relevant in terms of how they change the behavior of the user interface.

It takes only a moments reflection to realize that virtually **the only thing anyone cares about are the external empirical <u>functional properties</u> of their phone. The internal hardware and software is irrelevant.**

This focus on factual external functional relationships rather than opinions about internal properties is also illustrated by the following anecdote. A Radical Behaviorist and a cognitive neuroscientist walked into a philosopher's bar. The bartender says "free drinks to whichever of you can best tell me why this herring gull retrieves eggs that roll outside the nest." The Cognitivist thought about what

types of algorithms could result in egg retrieval and confidently said "when the egg position discrepancy detector is activated by an egg sufficiently out of position, it triggers the egg retrieval mechanism, and I can prove it. He then moved an egg in the nest 1/4 inch and the bird did nothing. He then moved it 1 foot from the nest and the bird retrieved it. He then smirked and said (a bit condescendingly) "and that's the way you do science my friends" because he was convinced he was clearly the winner. In point of fact however, the cognitivist said nothing more than what people already knew. When the egg gets away from the next, the gull retrieves it. The cognitivist simply provided a synonym (the cognitive process) for what everyone saw the gull do. It was nothing more than a restatement of the question! The Radical Behaviorist made eggs of different sizes, shapes, colors, and patterns, and placed them different distance from the nest and determined how retrieval changed as a function of each. The behaviorist then stated the environmental conditions that trigger egg retrieval and those that did not and said to the cognitivist "you fail to understand science. You should try your explanation and proof on someone other than your students. Even a philosopher knows you don't have an explanation, you have nothing more than a tautology." Then the behaviorist passed one of his free beers over to the hapless pedant and said "try reading Skinner in the original some time."

Externalistic objectively demonstrated events are labeled processes when they have an effect on a dependent entity In the egg retrieval example, a systematic characterization of how egg retrieval varied as a function of changes in the eggs would be labeled the causal process governing egg retrieval. As a second example, if a particular behavior is followed with a change in the environment such that the rate of that behavior increases then that functional relationship between the behavior and the outcome is labeled the process of reinforcement.

4. Behavior Analysis is Concerned with Understanding the Moment-to-Moment Changes in an Individual Organism's Semi-Permanent Adaptation to Covariance in the Environment That Emerges and is Lost Across the Seconds-to-Days Time Scale ("Learning")

Inanimate objects on a lifeless asteroid exist. The rocks lay on the ground and "just sit there" if some other lifeless asteroid crashes into the first asteroid then many of the rocks will be moved to a new location. (Things that are not alive can be made to move and those movements can be characterized by, predicted, and explained by, the principled processes of Newtonian physics.)

A wide variety of changes can occur in a wide variety of entities as the result of a wide variety of processes. Changes across various levels of molarity and time scales are systematically presented, compared, and contrasted in Chapter 4 of the present text.

A fundamentally important form of adaptation and the focus of behavior analysis occurs when the response to a stimulus that an individual living organism makes is semi-permanently changed by the exposure to covariance between events in the environment across the seconds to days time scale. A specific example of this process is the well-known

semi-permanent change in an individual pigeon's behavior by repeatedly presenting food presentation whenever it pecks, (i.e., Thorndikian reinforcement) or the semi-permanent change in an individual's behavior when a bell is repeatedly followed by meat powder (i.e., Pavlovian reinforcement).

Just how truly astounding this class of adaption is, can be easily illustrated. Suppose you walk up to a trash can and yell: "look out." It will just sit there. Suppose you do it 10 more times. It will just sit there all 10 times. Suppose you walk up to the trash can and kick it; it will slide across the floor. Suppose you do it 10 more times. It will slide across the floor all 10 times. There is nothing special about either inevitable unchanging and perfectly predictable outcome. Now suppose you correlate those two events: you walk up to the trash can, and yell lookout and kick it. The trash can will slide across the floor. Suppose you pair the events 10 more times – the trash can will slide across the floor the 10 more times you kick it. Then suppose you walk up to the trash can and only yell lookout. If the trash can then slid across the floor you would be shocked silly. It never moved when you simply yelled look out before.

On the other hand, if you had done the exact same procedure with a dog, you would not be surprised even though the dog is made up of the same materials that were in the trashcan (i.e., organic compounds).

It is self-evident that the dog is alive and the trash can is not. Many processes across many levels of molarity and time scales were involved in organic matter evolving into an escaping dog; **BUT** a spoonful of magic, or "know-what-to-do", or a space alien receiver is not among them.

The label for explaining the behavior of the dog as "the dog is alive and knows what to do" is a tautology and is **ignorance**. The label for the determination of the precise combination of external events that cause living organisms to react to environmental events across a relatively short time span is **behavior analysis**. In our example case, we are interested in what factors caused "running away" to the shout in a dog.

If life is a vehicle and learning is the steering wheel, then behavior analysis is focused on what turns the wheel not whether the wheel is made from steel or plastic or whether there are gears or levers instantiating the adaptation. For behavior analysis, the task is to document what environmental events cause what behavioral results.

There are two important distinctions between the behavior of the trash can and the behavior of the dog. First the dog's behavior to the yell changes or adapts with increasing experience. Secondly, that adaptation endures for a short time even after the correlation with the kick is removed. The dog continues to run following the yell for a few trials even after you stop kicking it. Behavior analysis is focused on organismic adaptation with these two characteristics, that occurs across the seconds to days time scale, as the result of the correlation of the two events.

An individual is seen as an entity that is, for the most part, a growing set of enduring characteristic and predictable new response patterns established by contingencies of functionally important events labeled reinforcers. As a result, understanding the effects of contingencies of reinforcement is the core of behavior

analysis. Additionally, because the task is to understand how an individual's behavior adapts as a function of increasing experience, the exclusive focus is on the causes of the moment-to-moment changes in the behavior of an individual. The average behavior of a group does not reveal how each individual came to behave the way they do. It does not provide information relevant to understanding the cause of individual differences.

It is essential to point out that behavior analysis does **NOT** assert that every behavioral adaptation of every animal on earth is the result of nothing other than reinforcement (as it is sometimes incorrectly argued). Rather, because semipermanent adaption across the seconds to days time scale that occurs as the result of exposure to covariance in the environment accounts for a significant portion of an individual's behavioral repertoire; it is therefore the prime candidate for the correct explanation for a significant portion of an individual's behavior.

The knowledge base of short time scale adaption in individuals is quite large and complex. It is covered as The Experimental Analysis of Behavior and is a full course.

B. Review of Examples of Behavior Analytic Explanations as Opposed to Non-Behavior Analytic Explanations

1. Single Neuron Organism

The touch made the organism move (externalistic); rather than the neuron (internalistic).

2. Referent of Knowledge

Knowledge is behavior under control of covariance in nature (externalistic) rather than a piece of meat or electrochemical activity in the brain (internalistic).

3. Cause of Egg Retrieval

The specification of the effects of color, size, and shape on egg retrieval (functional properties); rather than the activation of the egg retrieval center (internal cognitive processes).

4. Cause of Operation of Water Dispenser

What button to push (functional properties); rather than the can release cog activation circuit (internal process).

5. Cause of Smart Phone Functions

What hand motions cause what phone functionality (functional properties); rather than the characteristics of the CPU chip and the firmware causing that functionality (internal structure).

C. Grammar for Clearly Conceptualizing the Explanation for Behavior

1. Subject of Sentences Should be Behavior Rather than the Animal

"Key pecks followed by food increase in rate" (externalistic); rather than "the pigeon learns to peck when food follows the key peck" (internalistic).

2. Organism in Passive Rather Than Active Voice

"Key pecks occurred within 8 seconds of the illumination of the green light in the pigeon" (the pigeon is in the passive voice; key pecks are active voice); rather than "the pigeon pecked within 8 seconds of the illumination of the green light"; (the pigeon is in the active voice and is therefore the focus of the sentence.)

Pigeons in the active voice implies that key pecks come from the pigeon, rather than as the result of events in the environment.

D. Historical Origin of Behavior Analysis

Skinner's enormous impact on psychology began in the 1960's with the field's loss of faith in the Hullian paradigm even though Skinner's original position was first formally enunciated in 1938.

Skinner was the next step in the line from Aristotle, Galileo, Hobbes, Spencer, Sechenov, and Pavlov to Thorndike. Skinner did not invent science, he was not the first person to realize that short time scale ontogenic organismic adaptation occurred, nor was he even the first to realize or demonstrate the importance of the subsequent outcome of a behavior on the future probability of that behavior. His core idea of reinforcement was not fundamentally different than Thorndike's law of effect. However, he was the first to develop a comprehensive, coherent, complete, philosophically sound, experimentally based, productive paradigm for psychology. Skinner was an especially unabashed, forceful, articulate, and conceptually sophisticated spokesperson for evolving a science of behavior. Skinner labeled his seminal conceptualization of psychology Radical Behaviorism. The discipline is labeled Behavior Analysis.

At its core the fundamental tenets of Skinner's paradigm were:

1) The task of psychology is to understand the **behavior of organisms**, and Thorndikian short time scale adaptation accounts for the largest proportion of an individual's behavior;
2) Scientific determination of **functional properties** provides the only meaningful information bearing on short time scale adaptation;
3) A scientific experimental approach to psychology would have a wide range of **beneficial applications.**

Skinner eschewed explanations which he viewed as unproductive or unpragmatic.

1) Skinner rejected explanations based on how the empirical stimulus traveled through the body or came about within the nervous system.
2) Skinner also rejected hypotheses based on how non empirical internal processes cause behavior.

Skinner rejected these explanations because internalisms are simply not a pragmatic approach to solving problems. As previously discussed, inferred internal events or explanations cannot be resolved and even then they typically do not systematically connect behavior to their environmental causes.

It was not as if Skinner thought that no internal entities existed. Skinner was comfortable using the terms "brain" and what he labeled "private events" in a sentence. However, he limited himself to what could be productively said about internal events and processes.

Skinner's rejection of internal explanations was consistent with his rejection of arguments concerning philosophical realism (a real world exists). The fact is we cannot prove we or anything else is real. "Cogito cogito ergo cogito sum", is just as valid as "cogito ergo sum", so arguing about real reality is simply not pragmatic. His view was that research should not be seen as discovering the true real world, rather research simply specifies sets of functional relationships which allow us to function better. We are simply making better predictions and making a more coherent pragmatic explanatory system. Similarly, psychology is predicting behavior based on the environment not discovering the internal cause of the behavior. Skinner astutely pointed out that in the absence of evidence to the contrary, private events should be expected to function like any external behavior. In effect, private events were relegated to the status of useless curiosities.

Skinner's paradigm allowed the study of psychology to step out of the morass of unresolvable controversy which had trapped psychology in meaningless arguments for millennia. He noted that the knowledge generated and the enduring aspect of the great researchers across history was their documentation of the measurable changes in the object being researched as a function of measurable changes in the external environment rather than the hypotheses of the researchers about unmeasurable processes (which were almost always shown to be useless relatively soon after they were enunciated).

Skinner's conceptualization of the topic (moment-to-moment short time scale adaption in individuals via correlations in the environment); his explanatory approach (explanations as the specification of the functional properties); the elements of his explanatory system (objectively demonstrated entities, or strict externalism); and his development of a wide variety of applications of the knowledge base (behavior modification, cultural engineering, self managed life styles): defined a paradigm (Behavior Analysis), that was both practical and practicable. Skinner was the next step in the line from Bacon and Hume to Sechenov, Ebbinghaus, and Mach. As a result, his paradigm attracted an extensive and diverse base of enthusiastic adherents.

E. Conceptual Distinction: Radical Behaviorism Versus Simple Behaviorism (Palya's Version of the Distinction)

The history of behavioral approaches to psychology is the history of various attempts to prune paradigms of their unprovable or unproductive baggage such as the mind and other cognitive processes. Skinner proposed an approach labeled Radical Behaviorism. The present text asserts that Skinner took the bold step of focusing only on the necessary and sufficient empirical elements in organismic adaptation and limited his discussions to functional relationships between the environment and behavior and entirely removed unproductive discussions concerning why the animal responded. His view was that predicting one set of measures based on another set of measures is an inarguable and useful fact (i.e., pragmatic), whereas "why an animal does something" is rich ground for philosophical entanglements. This pragmatic approach to organismic adaptation is analogous to his rejection of discussions pertaining to the "real" world, and his position that research can best be characterized as only making predictions about one set of measures based on another set of measures.

It is of fundamental paradigmatic importance to distinguish between: 1) an examination into "the external factors that causes a person to choose to behave the way they do," and 2) an examination into "the objective environmental factors that cause one behavior to predominate over another." The latter is not only behavioral but is Radical Behaviorism because the entire explanation, both the cause and result, is constructed **exclusively** from objective environmental factors. The internal person wanting or choosing to behave or the internal biology making a behavior occur is irrelevant in Radical Behaviorism. As a second example, EAB is not the study of how a pigeon learns to key peck in some particular way in order to get food; rather, it is the study of the factors that establish and control key pecking.

The difference in conceptualization provided in the two examples is subtle but is a fundamental and essential defining property of Radical Behaviorism. To fail to understand the distinction (a person choosing vs. behavior changing) is to miss the fundamental raison d'être of Radical Behaviorism. Simply put, Radical Behaviorism is a thorough going behaviorism not a behavioral frosting on what is basically mentalism. The research does not discover why an internal entity came to behave the way it did, nor how an environmental event had any effect on the internal properties of an organism. Rather, Radical Behaviorism focuses on the pragmatic objective of specifying a behavior given environmental events.

This distinction is illustrated in Figure 10.5. The left portion illustrates causal environmental factors and the resulting behavior with respect to an organism. The image is an organism reacting to a stimulus. The right portion of the figure better characterizes Radical Behaviorism. It portrays a behavior as a function of environmental influences. In the rightmost segment of the figure, the subject of the sentence must be the environment rather than the organism because there is no organism portrayed. It is irrelevant to the explanation just as the really real world is irrelevant to the value of any functional relationships measured by science. It is what makes radical behaviorism, "radical"

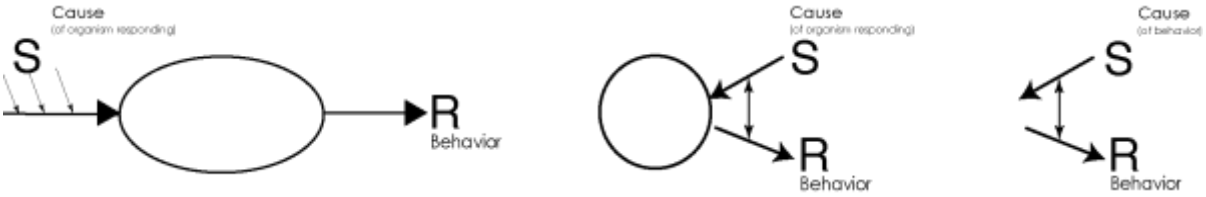

Figure 10.5 The left section of this figure illustrates environmental events acting on an organism to cause the organism to behave in some way. The center section of the figure illustrates the same thing but diminishes the role of the organism by focusing on the causal factors and the behavior. The rightmost section of the figure more formally focuses on the relationship between the environmental factors which control the behavior and more formally eliminates the organism from consideration.

In that regard, when asked "is that why the organism reacted that way?", a radical behaviorist would answer: "First I have no idea. I am only telling you what behaviors will occur given that experience" (thus limiting discussion to external events and limiting arguments to resolvable issues). "Secondly, in the absence of any contravening proof, I presume that whatever is going on inside the organism follows the same laws that I am researching."

Go back to the first paragraph in this section (i.e., "E"). Note that the first example is about a person and is **not** a Radical Behavioral statement, and the second version is about a behavior and **is** Radical Behaviorism. In the second example, the first version is about a pigeon learning to get food and is **not** a Radical Behavioral statement, while the second version is about factors that control behavior and **is** Radical Behavioral.

A radical behavioral sentence is exemplified by one whose subject is the behavior not one whose subject is a organism. Sentences about people or pigeons are not so much wrong, as simply emphasizing the wrong explanatory priority because they lead the reader to wonder what about the animal caused the behavior. Sentences about behavior lead to questions about how the environment causes the behavior. A Radical Behavioral approach focuses on what is ("to be" verbs) while mentalism and traditional behavioral approaches focus on what the person wants or does ("to do" verbs). A simple way to get a clear idea of the difference between simple behaviorism and Radical Behaviorism is to describe a procedure of shaping a pigeon to peck a key without any reference to the pigeon whatsoever (including any synonym for the pigeon).

1. Conceptual Follow-up: Best Practice Versus Common Practice

It is not as if there is anything necessarily and irretrievably destructive about 1) depicting the processes controlling the behavior of an organism as it is in the left portion of Figure 10.5; or 2) even saying "the child knew what to do." A diagram including an organism or a sentence with the organism as the subject does not require that the cause of the behavior comes from within the organism itself and the referent for the "child knowing" could be the child behaving analogous to "that sack of books is trying to fall".

The issue is where does the figure or the choice of the subject for the sentence

suggest that the cause of the behavior is to be found? With Radical Behaviorism Skinner simply tried to optimize the analysis of behavior by limiting discussion to the external functional relationships and avoid linguistic constructions that led to the postulation of inferred entities. This issue is ideally illustrated by the philosopher's bar anecdote and the explanation for egg retrieval in the gull. Both the cognitivist and the radical behaviorist were led to look for the cause of the behavior to be explained in their description of the behavior. The cognitivist saw an internalism causing a goose to retrieve eggs. The radical behaviorist saw egg retrieval behavior caused by the environment when eggs were outside the nest.

Radical behaviorism is a structuring of the environment to encourage the desired behavior from its practitioners, not some shibboleth or system to assign lower status to someone who speaks "incorrectly." It is nothing more than staying focused on the necessary and sufficient elements of the field.

2. Historical Evolution of the Conceptualization of the Cause of an Individual Organism's Behavior

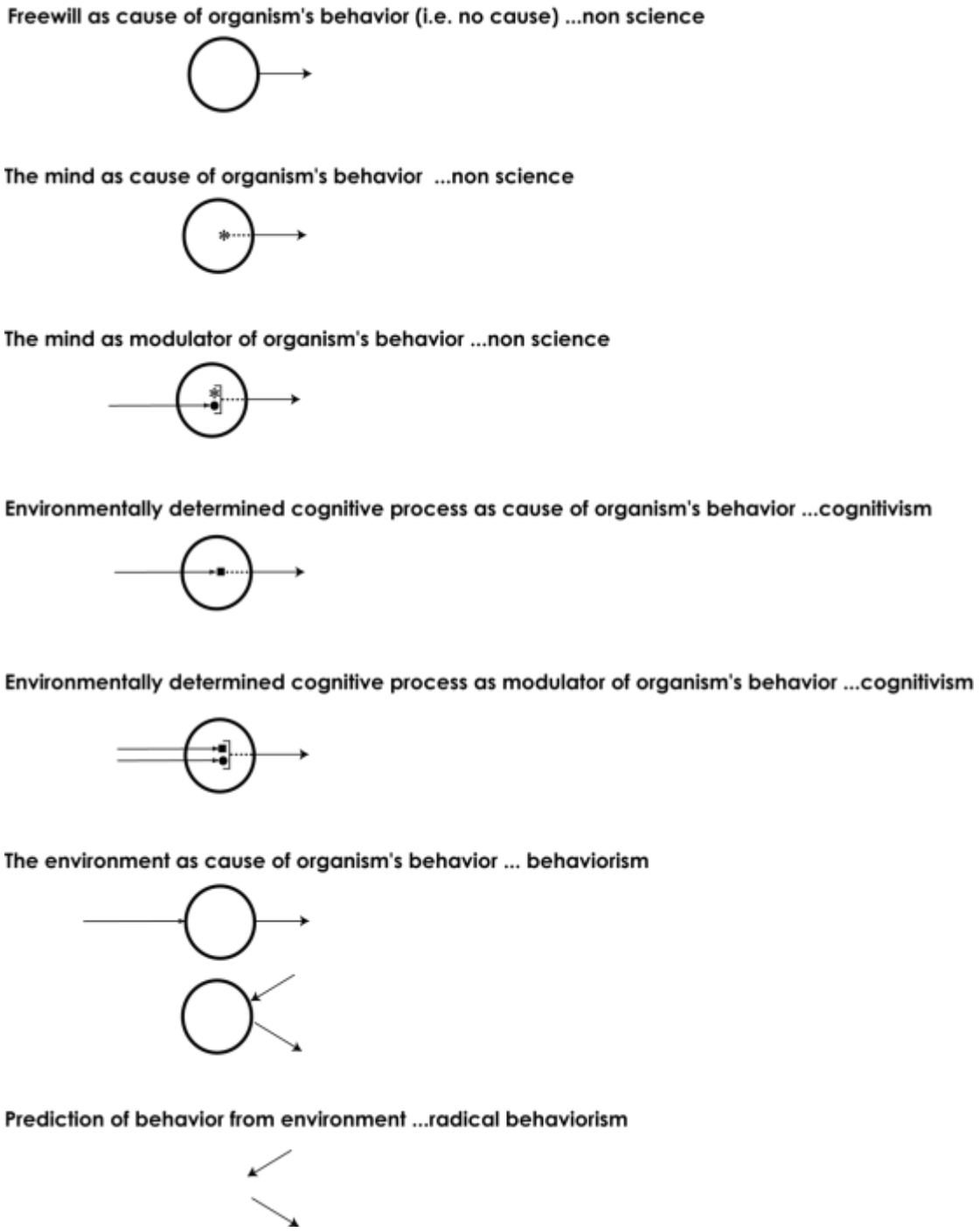

Figure 10.6

Chapter 11
Optimization of Knowledge Gathering / Problem Solving (Research): Reliability

I. Reliability Maximization

A. Understood facts
   1. empirical
   2. multiple converging evidence
   3. consistency with paradigmatic framework of science
   4. consensually validated
   5. operationally / functionally defined
      a. explicit definitions

B. Quantified descriptions
   1. conceptual precursor: measurement or forming equivalents or analogs to quantities in the natural world
      a. reliability
         i. interobserver reliability
         ii. intraobserver reliability
      b. validity
         i. class of of validity in measurements
            (1) numerical validity
                (a) systematic invalidity
                (b) unsystematic invalidity
            (2) empirical validity
            (3) inferential validity
                (a) kind of validity
                    ((i)) convergent validity
                    ((ii)) divergent validity
                (b) type of inference or its source and destination
                    ((i)) behavior-to-construct inference
                    ((ii)) behavior-to-behavior inference
      c. amount of information retained in language equivalent: measurement scales
         i. nominal numbers
         ii. ordinal numbers
         iii. interval numbers
         iv. ratio numbers
         v. summary
      d. type of increment

2. conceptual precursor: grouping
    a. assumptions
        i. measure + random error
        ii. measure + effect
3. conceptual precursor: graphical representation of group data
    a. distance as representing quantity
    b. space as characterizing group data
        i. tally graph
        ii. bar graph
            (1) nominal values in bar graphs
            (2) other than nominal values in bar graphs
        iii. histogram
        iv. frequency polygon
        v. frequency distribution
    c. conceptual follow-up: information and grain in graphical presentations
4. quantifying group data
    a. central tendency
    b. dispersion
    c. shape of distribution

C. Maximized variability contained within rule
D. Appropriate research technique for given subject, apparatus, and procedure
    1. familiar context
    2. procedurally accurate
    3. technologically sophisticated
    4. large signal-to-noise ratio
    5. correct elimination of confounds or correct experimental design
        a. single-subject designs
        b. group designs
            i. elimination
            ii. pair-wise matching
            iii. explicit group balancing
            iv. balancing by theoretical notions
            v. balancing by randomization
    6. correct application of analytical technique “meeting the assumptions”
E. Use of a revealing analytical perspective
    1. correct specification of controlling and controlled variables or relevant independent and dependent variables as axes
    2. correct level of analysis or transformation of the data
F. Insightful tactics

CHAPTER 11

Optimization of Knowledge Gathering / Problem Solving (Research): Reliability

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Initially the text developed the rationale for why being a scientific psychologist or being a behavior analyst is worth the effort. The meaning of the concept labeled "science" was then developed by discussing its meaning and properties, the rationale underlying its procedures, its context, and the meaning of its products, "knowledge" and "explanation". Based on that deeper understanding of the fundamentals underlying science, a detailed comparison and evaluation of non-behavioral and behavioral explanations was then provided in the two chapters we just covered.

The next three chapters provide guidelines pertaining to the production of, or consumption of the knowledge generated by behavior analysis. In sum, whether you are generating research or simply reading a research paper you must assure that that research provides sufficient reliability, detectability, generality, and meaningfulness.

Chapters 11, 12 and 13 are organized around the issue of optimizing research. Some of the fundamental principles that optimize research have other consequences, such as allowing you to provide a better explanation, or giving you a better chance to accomplish your goals. As a result, they have been presented in those contexts in the previous chapters focused on those issues. In the next three chapters, we want to review and think about those familiar elements in terms of their bearing on the optimization of research. Some of the material is relatively basic. If you are thoroughly familiar with it see it as a easy review and only presenting the topic in a new context, If the issue or its nuances are new to you see it a something you will need to know before you graduate.

The issues of reliability, detectability, generality, and meaningfulness are applicable to all types of research output. They can be applied to everything from simple observations to explanations, theories, and models.

Various statistics are available for quantifying the degree of reliability, detectability, generality, or meaningfulness in knowledge gathering or research. But, before assessing those attributes in your research, it only makes sense to first take every step possible to maximize those dimensions.

I. Reliability Maximization

Simply put, the same procedure must produce the same results each time it is carried out and the researcher must do everything possible to make that the

case. An important meaning of truth or a fact is that the result is repeatable. When adding a column of numbers, the answer must be the same every time the numbers are added. Results that are inconsistent within a study or inconsistent with the literature are of little use because we don't know how to interpret the discrepancies. In principle the existing knowledge base could be wrong or the new research finding could be wrong. However, the existing database and conceptual scheme is always given the benefit of the doubt.

Before a functional relationship, or an event, can be considered a fact or true, it must be possible for each person to verify its existence for themselves. The same procedure must produce the same result. For example, when you can add up a column of numbers several times and always get the same answer then it is relatively likely that you have added the numbers correctly. When someone else independently checks your addition and also gets the same answer then your confidence is even greater that you have the "true" answer. This is because more than one person will be able to repeat or replicate a true event.

A repeatable finding is one whose controlling factors have been correctly identified. If you completely understand something, you can generally do what it takes to make it happen or to make it stop. If you do not really understand a phenomenon you will not be able to reliably control it, because it will come and go according to its true determinants and not necessarily occur in conjunction with your adventitious manipulations. If you are a creative cook, you want to be able to specify a recipe so that other people can obtain the same results. Likewise, if you are a consumer of recipes then you want to be assured that if you follow the procedures you will get something good to consume. Psychologists want to be assured that they will get as good a result as those found in the publication.

If you wish, you can view this chapter allegorically. It's as if the variables that make things happen are invisible demons because they are not always immediately apparent or clearly understood. This chapter present the rules by which you can "chain the demons." If you understand them and control for them (know their name), you can keep them from misbehaving. The more demons you have no control over the more often flaws will occur in your work. Directly stated, if you follow the guidelines in this chapter, then you will be more likely to accomplish productive work without the risk of being tricked by an illusion or misunderstanding.

It is one thing to know the need for reliability in the research we conduct or use; it is another thing to know how to maximize it. Several specific ways have evolved which enormously facilitate your ability to maximize reliability, and thereby separate fact from fiction or to tell the truth. These rules assure that you are connected to reality by maintaining your focus on the necessity that others be able to repeat your findings.

A. Understood Facts

In order to maximize reliability, it is important to first assure that you are dealing with reliable entities or those things labeled true facts.

1. Empirical

Empirical things are those things that can be experienced with the senses directly.

2. Multiple Converging Evidence

The more evidence from the wider variety of sources the better. A measure determined by several different independent methods based on different assumptions is much more likely to be reliable than a measure determined by only one method. If you have an inferred measure like response strength and it is equally well measured by latency, rate, errors, force of pull, and duration, then it is more likely to be reliable than if it were measured only in one way such as only rate. In point of fact, it could be argued that unless it is measured in multiple ways, and those measures are very highly correlated, the intervening concept such as response strength is lost somewhere between being misguided and foolish.

3. Consistency with Paradigmatic Framework of Science

A finding which is consistent with great sections of the interlocking body of knowledge and that is not incompatible with any basic understandings is more likely to be reliable than a finding that is inconsistent with much of our acquired knowledge. A causal relationship that is consistent with a great body of knowledge is more believable than an effect that is simply unlikely to occur by chance alone. Part of the task of the discussion section of a journal article is to establish continuity with the theoretical net or paradigm for this very reason.

Your task is to make sense out of the environment, not to show how you cannot make sense out of it. "Scientific glory" goes to the person who makes sense out of a finding (shows how it is consistent with many things), not to someone who throws out a fact which may be true and important, or may be an error and irrelevant. It is your ability to find out why your result is the same as everything we know that makes it important not your saying that something doesn't make any sense to you, and therefore is a scientific breakthrough.

4. Consensually Validated

The more observers and the more diverse the observers, who abide by the paradigmatic rules of behavior analysis, who identically experience the event; then the more likely the finding is to be reliable.

5. Operationally / Functionally Defined

Clarity and precision in the specifications of the referent for the words or the more unambiguous the criteria with which to separate the elements being discussed, the better.

a. Explicit Definitions

The use of more explicit and clearer operational/functional definitions increases the reliability of a functional relationship or an event. We must clearly include the elements that are part of the meaning and exclude the elements that are not a part of the meaning. We must have explicit and precise boundaries on our definitions. If the boundary of the set containing the elements to be measured changes or is poorly understood, then any measure of the set can, as a result, vary. If reliability is getting-the-same-answer-when-adding-up-a-column-of-numbers-multiple-times, then there must be some clear way to distinguish what "numbers" are to be added up and which are not to be included otherwise the answer will vary.

Examples that stem from an unclear or ambiguous reference are plentiful. Often, our verbal description of something misses essential aspects of what we meant and can result in other people having an interpretation of the words that differs dramatically from what we intended. For example: Recall the evil genie trick: You wish to live forever? No problem you will live forever. What? You did not want to age? Sorry, you didn't ask for that. A second example is given by the definition of punishment. Often there is substantial disagreement over whether or not "punishment" works. The disagreement is specious. If we were to operationalize the definitions that the disagreeing parties were using, we might hear "I punished Johnny by no longer helping him develop into a better fully functioning person. I stopped criticizing everything he did" or I punished the pigeon by providing "20 micro volts of electricity delivered to the floor" (pigeon feet are insulators). An example alternative to these useless definitions is "the consequence necessary to reduce the rate of the behavior by one half."

It should be obvious that communication must ultimately be based on operational/functional definitions. The next time you have a disagreement with someone, try defining the words at the focus of the disagreement. The disagreement will probably disappear.

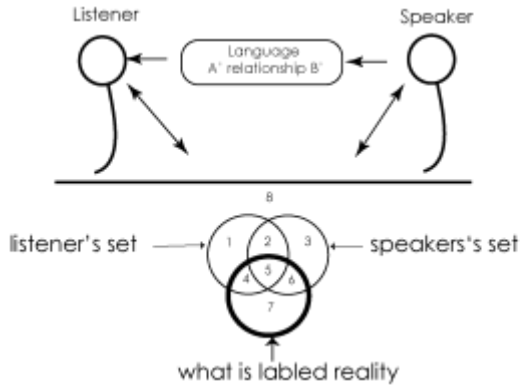
B. Quantified Descriptions

Accurately and precisely describing and quantifying what is observed makes it more likely that all observers will agree on exactly what did in fact happen thereby optimizing reliability. Quantification is the mapping of the magnitude of a thing into the language system, and could be seen as the systematic choice of modifiers for nouns, such as "larger or longer," or what would be better "2.4 times larger" or "140 meters". Our term must be unambiguous. Large and small as modifiers could take on meaning to suit the user in their subjective reality. Imagine for example, loaning people money without quantified descriptions of the amount. Imagine a football game without a chain and the referee could just say "well it seems like a first down to me." Alchemy changed to chemistry when explicit quantification was required.

1. Conceptual Precursor: Measurement or Forming Equivalents or Analogs to Quantities in the Natural World

Quantification or "measurement" can be seen as the conversion of some property of an event in nature into some elements in an equivalent system such as language or mathematics or from the equivalent system to an empirical prediction of an event in nature. The issue is how perfectly and completely does the listener know what the speaker experienced?

Figure 11.1 presents the possible outcomes in terms of signal detection terminology. There are many sources of error going; 1) from an event in nature, 2) through an observer, 3) into a language, 4) to a listener, and 5) out to the identification of the original referent.



what is labled reality	4,5,6,7
speaker's elements	2,3,5,6
listener's elements	1,2,4,5

speaker's decisions	correct detection	5,6
	correct rejection	8
	false alarm	2,3
	miss	4,7

		wrt speaker	wrt reality
listener's decisions	correct detection	2,5	4,5
	correct rejecction	7,8	8,3
	false alarm	1,4	1,2
	miss	3,6	6,7

Figure 11.1 A re-presentation of Figure 8.4. It provides a depiction of a speaker under the control of some referent (A relationship B) in nature who puts that relationship into measurements or words. The listener under the control of that verbal behavior either correctly or incorrectly acts with respect to the original relationship in nature. The figure provides a depiction and label for each segment of the communication

The amount of information or accuracy of the communication can vary. Additionally, quantitative relationships apparent in nature may not be available in the converted information, or information may be added. The error can occur at the original translation of the relationship into verbal behavior, or in the translation of the verbal behavior into a prediction

a. Reliability

The conversion to and from the equivalent system must be reliable. Reliability refers to the ability to repeat a measure, observation, or functional relationship. Metaphorically, if someone shot ten arrows at a target, it is how close together the ten arrows land. Interestingly enough, in terms of only reliability, they can be way off target as long as they are close together. Clearly the conversion to the equivalent system must index the events in some repeatable way if you want to maximize reliability. There are two types of reliability.

i. Interobserver Reliability

In this type of measurement, there is a mapping of events or relationships in the natural world into language. There is great emphasis on reliability across individuals. For example, if something is 140 meters long today for you, it must be 140 meters long tomorrow for someone else. Counting objects is another example. The count must be reliable across observers. For example, "one chicken, two chickens, three chickens, etc." Weighing objects is yet another example. The weight must be reliable across the different people measuring the weight, for example, "one pound, two pounds, etc." The measures must be the same for all people doing the weighing under all conditions.

ii. Intraobserver Reliability

A variety of operations are available to attach a number to a comparison that occurred in nature within an individual, where that assignment need be relevant or applicable to only that particular single individual, for example, "psychological scaling." In this case, reliability within an individual is sought but the differences between individuals is the dependent variable or the information being focused upon. The evaluation of things is an example: For Subject 1, movie A is the best and movie E is second best." For subject 2, movie G is best and movie M is second best. Within each subject the evaluation must be reliable The relative value of the two movies for a particular subject stays the same, however it is the difference in the evaluation of the two observers that is the focus of the research.

b. Validity

The measure to and from the equivalent system must be valid. Validity refers to the degree to which the measures correctly index the entity being measured. Metaphorically, if someone shot ten arrows at a target, it is how close the ten arrows came to the bullseye. Interestingly enough, in terms of only validity they can be all over the place as long as their mean is dead center on the target. The conversion must generate information that reflects the actual attributes that are of interest in nature. With respect to the speaker, these are labeled 5 and 6 in Figure 11.1. With respect to the listener, these are labeled 4 and 5 in Figure 11.1. These sets must be as large as possible. Invalidity can occur if inappropriate measurement techniques are used. The three general classes of invalidity in measurements are numerical, empirical, and inferential.

i. Class of Validity in Measurements

(1) Numerical validity

(a) Systematic invalidity

Systematic errors change a measure by a constant amount in a constant direction, such as the effect of a broken ruler. For example, if a one-inch piece has been broken off a ruler, each measure will be one inch more than it should be. These errors change the measure but can be easily corrected if they are constant and known. Simply subtracting one inch (in this example) from each measurement results in the correct measurement.

(b) Unsystematic invalidity

Unsystematic errors change a measure in unsystematic ways, sometimes adding, sometimes subtracting, sometimes by a large amount, sometimes by a small amount. These errors change each individual score but do not change the mean of all the scores if the errors are truly random. If the error is truly random, then the mean of the measurements is correct and need not be corrected because the mean of a random error is zero. However, each individual measure is wrong and cannot be corrected. If the errors are not specifiable and not truly random, then both the individual measures and the mean of those measures are wrong and no correction is possible to either the individuals or to the mean.

(2) Empirical validity

For a measure to be valid, you must measure what you think you are measuring. You must be correctly connected to reality.

For example, if you read a humidity gauge and believe you are reading a temperature gauge it is extremely unlikely that people will be able to replicate your effect when they follow your instructions to set the "temperature" to a certain value. Alternatively, if you view a thermometer from an extreme angle and get a parallax error in your measure, then your measure will not be replicable by either people who measure the temperature correctly or who measure it with their own inaccuracy. You must be correctly connected to reality.

(3) Inferential validity

If something is measured indirectly, it must be assured that the inference is correct or that you have measured what you thought you measured. Indirect measures are prone to error, invalidity, and unreliability. For example, if you ask people what they will do in a crisis, what you are actually measuring is what they tell you they will do in a crisis; you cannot automatically infer that they will actually do what they tell you they would do. As a second example, researchers have put pigeons on a schedule where a key peck would avoid shock. They found that pigeons wouldn't peck to avoid shock. They did not prove that pigeons won't avoid shock. They'll fly away to avoid any pain, including shock, There is a difference between showing a pigeon will not peck to avoid shock and showing a

pigeon will not avoid shock. You must be correctly connected to reality.

This is the reason behavior analysts are exclusively focused on direct measures and eschew the use of indirect measures. This section is to simply provide you with familiarity with the terms rather with procedures to use inference. It is important to realize the difference between directly measuring the ultimate thing of interest and measuring one thing and hoping that it will give information about another.

(a) Kind of validity

((i)) convergent validity

The first kind of inferential validity requires that all measures thought to indicate a construct such as anger must be highly correlated; or show convergent validity.

((ii)) divergent validity

The second kind of inferential validity requires that all measures thought to be independent of the construct must be uncorrelated with all measures of the construct; or show divergent validity.

(b) Type of Inference or its Source and Destination

((i)) Behavior-to-Construct Inference

In this case, a behavior that can be measured is used to provide information about a construct that cannot be measured directly. For instance: one statement is "the gun shot made John afraid and he ran because he was afraid." Alternatively, it could be said 'the gun shot made John run" only if fear can be measured in some way other than running is the first statement meaningfully different than the first.

((ii)) Behavior-to-Behavior Inference

In this case, one behavior is used to provide information about a second behavior. For example, we could assert that turning away with eyes wide open and taking a deep breath predicts screaming.

c. Amount of Information Retained in Language Equivalent: Measurement Scales

An important issue in forming language equivalents to events in the natural world involves how much information is retained

Elements of a group of things are frequently differentiated by assigning different elements different numerals. Assigning a numeral to an instance or an occurrence of something does not always mean the same thing. "Seven" is not the same as "seven" and both are completely different than "seven," whereas "seven"

is wholly different than the previous three. There are four different things that could be meant by the numerals (for example seven) assigned to the elements of a group. Unfortunately, they are essentially homonyms – same word: "seven" or "7," but each with a different meaning.

The following four types of numbering systems differentiate elements of a group. Each category implies successively more about the quality or quantity of that difference, but unfortunately they all use the same numerals. You must remember that some forms of differentiation say more about the nature of the differences between measures than others.

If we see three people who weigh 150, 200, and 250 pounds, we can say they are of : 1) class majestic, regal, and imperial; or 2) heavy, heavier, and heaviest; or 3) size 10, 20, and 30; or 4) weight 150 pounds, 200 pounds, and 250 pounds. They are, in fact, ordered in what is called a ratio scale (i.e., 150, 200, 250 pounds). However, we may not always have, or even want, every aspect of information available in nature. In our technical terminology, their ordering could be nominal, ordinal, interval or ratio scales depending on how much information we can or want to communicate. Measurement scales formalize the specification of how much information is retained in the language with respect to the variables of interest.

i. Nominal Numbers

In this use of numbers, the only thing we know is that the three people have different weights. We don't even know which person is heaviest. We simply give them three different names (1, 2, and 3) or if we use English rather than numbers then majestic, regal, and imperial. No information is provided about which is larger – maybe one is larger, maybe two, maybe three. All the people with the same weight (e.g., 150) go into the same class (e.g., 1) (or regal). This is like assigning different Chinese foods different numbers. When you call in your order, you can ask for three number 15s and one number 12. The only thing that is implied by a nominal number is that its value is different from any other nominal number and all things with the same number are the same thing. Someone else can order number 15 and will get the same dish. In this case, you have used numbers in the same way you would use words like Mongolian Beef and Szechwan Shrimp. You are using the number as a name or label, but no quantitative relationship such as bigger or heavier is implied. You are classifying the item. You may not substitute a Kung Pao chicken for a Mongolian Beef dinner. You may not put red glass in the pile of green glass. You may not put something with the properties labeled with the number 23 into the category reserved for items with the property labeled 14. The numbers tell you nothing other than the categories are different. You may not add, subtract, multiply, or divide the numbers meaningfully because they have no specified relationship to each other. You cannot subtract a circle from a pile containing only squares. The Chinese restaurant may not send one number 57 (15 + 15 + 15 + 12) instead of three 15s and one 12. Removing a receiver (Player Number 83) from one football team is not equivalent to removing the entire backfield; quarterback, halfbacks, and fullback

(players numbered 12, 20, 21, 30) from the other. Any change is a difference in kind not a difference in amount. If you found two "lucky" numbers on a roulette wheel, you could not play their mean and be twice as lucky. You cannot do arithmetic type operations to the numbers because they are nothing more than names and have no pre-specified relationship to each other. It is nothing more than apples and oranges. General Tso's Chicken (#30) is not twice as good as Szechuan Chicken (#15). The different numbers in this class could be thought of as representing a qualitative change.

There are three subclasses of nominal numbers: 1) identification – each individual has a different number, e.g., ID numbers; 2) categorization, e.g., blue = 1, green = 2 and red = 3; and 3) dichotomization – all events are dichotomized into two groups, e.g., male = 1 and female = 0.

ii. Ordinal Numbers

In this case, the three people from the original example are only specified as heavy, heavier, and heaviest when the numbers 1, 2 and 3 are used. The numbers indicate the rank. You know the person that is 3 (or heaviest) weighs more than the person that is 2 (or heavier) and that the person that is 2 (or heavier) weighs more than the person who is only 1 (or heavy). This system of numbers includes all the characteristics of nominal numbers (i.e., each class is different). It also implies that larger numbers represent quantities that are larger than the smaller numbers: 2 weighs more than 1, 3 weighs more than 2. However, the amount of difference between numbers is not necessarily the same. An example of this type of difference is the finish order in a race. You may not want to know how long it took each person to run the race; you may only want to know who came in first. The difference between the first and second runner may not be the same as the difference between the second and third-place runner. It is not appropriate to say that the second (2) place runner took twice as long as the first (1) place runner, and that the third (3) place runner took three times as long as the first (1) place runner. It is also inappropriate to believe that the difference between the first and second place runner is the same as that between the second and third place runner.

Figure 11.2 Illustration of the finish order in a race with the x-axis depicting that the relative spacing of the first, second, and third place runners can be different.

Figure 11.2 spatially represents that the interval between the numbers in an ordinal scale (such as finish order in a race) may not be the same. Subjective scaling indices such as rating, ranking, and pair comparisons are typically ordinal numbers.

iii. Interval Numbers

In this case, the three people from the original example are only specified as size 1, 2, and 3. You know that the sizes are different (nominal); you know which is bigger, or how they are ranked (ordinal); and you also know that the intervals between each incrementally larger digit are equal (but 1, 2, and 4 would not be equally spaced, of course). You know that the person of size 3 is as much bigger than 2, as 2 is bigger than size 1, but you do not know that size 2 is twice as big as size 1. Recall their actual weights, 200 pounds is not twice as heavy as 150 pounds.

To review, in this system all the properties of nominal and ordinal numbers are included, in addition, the intervals between numbers are also equal. The difference between numbers is therefore the same. From the original example, the difference between the people is 50 pounds, for a different example 36 degrees Celsius is the same amount above 35 degrees as 200 degrees is above 199 degrees. One degree is equal to one degree. However, interval numbers lack a true zero. 100 degrees is not twice as hot as 50 degrees. Using a more obvious representation, (100 + x) degrees is not two times larger than (50 + x) degrees because the x term would also have to be considered. Figure 11.3 below illustrates this effect with the arbitrary zero axis as a dotted line and the true zero-point axis as a solid line. While 4 is twice as high above the arbitrary axis as 2, it is not twice as high above the real origin. It can be seen that the true measure can be like an entire iceberg while the measure based on an arbitrary zero measure (an interval number) is like what is above the surface of the water. Twice as high above the water is not the same as twice as high altogether, in fact, if the icebergs move to fresh water their relative size above the water will change.

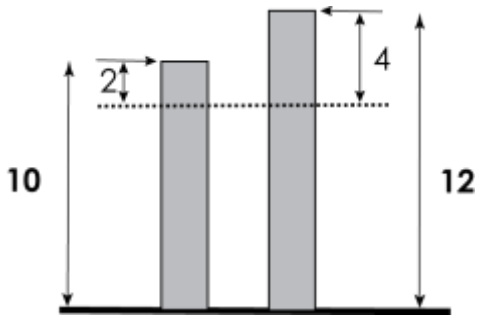


Figure 11.3 An illustration of a bar 2 units and a bar 4 units above an arbitrary zero point (the dotted line) with the actual zero point designated by the lower thick line. The bar labeled 4 is not twice as long as the bar labeled 2.

iv. Ratio Numbers

In this case, the three people from the original example are specified to weigh 150, 200, and 250 pounds. In this system, all the above attributes of the other number systems are included. In addition, zero means the absence of the property. You could have zero pounds of people in an elevator. If one elevator could carry 1000 pounds of people, then one that could carry 2000 pounds could carry twice as

many pounds. In the Kelvin scale of temperature, zero degrees means absolute zero. It is the absence of molecular motion and therefore the absence of temperature. Two degrees Kelvin is twice as hot as 1 degree Kelvin. Ratio numbers are what average people mean when they talk without qualifications about numbers.

v. Summary

The following figure illustrates measurement scales.

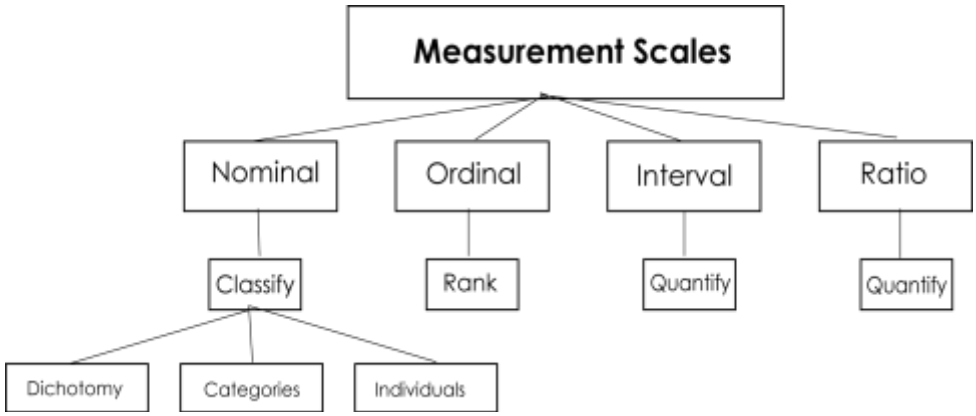


Figure 11.4 Labels for the four types of measurement scales with the three types of nominal categories depicted.

d. Type of Increment

The available values which the numbers can, in principle, take, or the "increment" type also varies. Some variables increase only in whole steps. They are referred to as discrete variables, e.g., family size increases only in whole steps - 1 child, 2 children, 3 children, etc. Continuous variables on the other hand can have any value in between. In actuality there are an infinite number of values between 1 and 2, e.g., weight or height can vary in steps of any size 100, 100.1, 100.01, 100.001, etc.

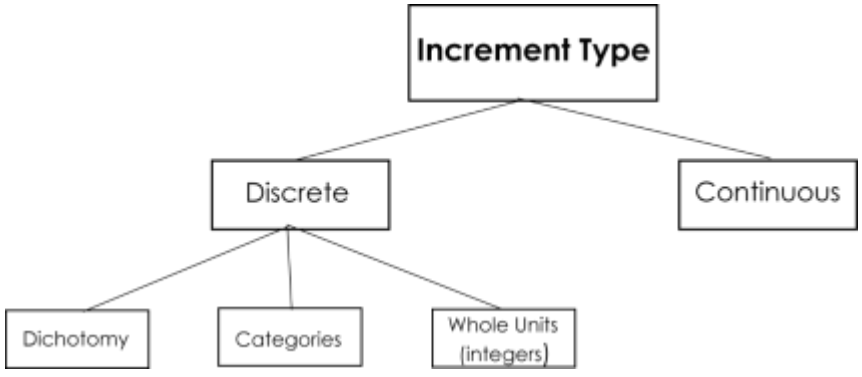


Figure 11.5 Labels for the two types of increment between consecutive numbers with the three types of discrete steps depicted.

Each type of variable can therefore be categorized with: 1) type of measurement scale and, 2) type of step; for example, "discrete interval" or "continuous ratio." It would not be meaningful to use a continuous step type with a nominal or ordinal scale.

	Continuous	Discrete
Ratio		
Interval		
Ordinal	not meaningful	
Nominal	not meaningful	

Table 11.1 A contingency diagram of the intersections of type of increment and the type of measurement scale.

2. Conceptual Precursor: Grouping

Even if the boundary of a set is precisely defined there may be variability in the elements within that set. Groups are homogeneous only in the dimension used to define the group. In other dimensions a group can show much diversity. Even though we have separated wheat from chaff, within our bag of wheat the kernel sizes, colors, weights, or protein content may vary. A pile of bricks is not the same as a pack of dogs but both the individual bricks and individual dogs differ from one another. The bricks can vary in weight and color and so can the dogs. When forming a group based on gender one ignores eye color. It can be seen that the rules which are used to define the group can be shifted such to include more or less variety. A group could be formed of blue-eyed males, or males between 18 and 20 with 3 years of college, or live organisms, etc.

When you obtain one score from some set, you have a datum that is easy to deal with, you just write it down. When you obtain a second measure of the same attribute from that same set the situation can change, the measurement may be the same as the first or it may differ. To use a specific example, suppose you gave an IQ test (the measure) three times to a person (the set). If they got the same score all three times then presumably you know their IQ, the characterization of the set was easy; however, if they got three different scores on the IQ test then the situation is much more complicated. Do you use only the first score, only the last, the best, the worst, or do you take the mean? What you do depends on what you believe is causing the difference. In sum, you must consider the scores as the same (one set) or different (three sets) before deciding on the value of the IQ. This task could be conceptualized as deciding which measures apply to the person and which do not.

a. Assumptions

i. Measure + Random Error

The first point of view is that IQ, or whatever was being measured, actually

remained constant and that the variation was caused by random measurement errors. As a result, the variation is considered meaningless and is ignored. This perspective is labeled "true score theory" and was presented as a reaction strategy to residual variance in Chapter 5. In this case the average of all the measurements would be the true measurement because the measurement errors are random and will, therefore, cancel out. A random error cancels out because it varies above and below the true value equally. This is saying that each measurement is made up of the true measurement and some random error, and that the variation in the measure is caused by the error of measurement, not changes in the thing being measured.

ii. Measure + Effect

The alternative point of view to deal with differences in measurement is to assume that the difference may be the result of an important systematic independent variable in which you should be specifically interested. For example, if you gave the tests consecutively, without any interruption, it may very well be that the person was getting tired and that the steady downward trend of the scores represented an important effect and not simply error of measurement. In this case, it would not be appropriate to average the individual test scores to determine the "true" measurement.

In the behavioral sciences, if you average across groups of individuals you are, in effect, saying that any differences between those groups of individuals are only errors of measurement and that all the groups are actually the same. If you average across individuals, you are assuming that individual differences are only errors of measurement and that all the individuals are actually identical. If you average across days for each individual, you assume that daily variations are only error, but the differences between individuals is important. If you average across a session for each individual for each day, you assume that no meaningful systematic effect is occurring within a session but that each individual and each specific day is important. It is very important to realize that any systematic effect which occurs across the dimension across which you are averaging becomes a confound. At best, you will be ignoring a source of variance at worst your interpretation of the data will be wrong.

Obviously, a decision as to what is going to be considered error or "noise" and what is to be considered a potentially important variable must be made before any averaging or grouping is done. How different assumptions of what variability is to be considered important and what variability is to be considered error or noise is the difference between an ideographic technique (a single subject under a wide variety of circumstances, e.g., Skinnerian or behavior analytic research) and a nomothetic technique (comparison of the averages of the performance of groups of subjects (e.g., an approach typified by classical Hullian research and much of the cognitive literature) as well as difference between the fields of Psychology and Sociology. Psychology is the study of the differences between individuals, whereas Sociology is the study of the differences between groups with the differences between individuals considered as error of measurement.

Once the determination of the appropriate level of grouping has been achieved various methods of graphical illustration and quantitative measurement for that group are then available. However, it should always be kept in mind that a choice of what to average across is a deliberate choice of what is to be considered irrelevant noise and what is to be considered an important subject matter of the discipline.

3. Conceptual Precursor: Graphical Representation of Group Data

a. Distance as Representing Quantity

Numbers can be represented by distance from an origin along perpendicular axes. Distance from the origin to the right or upward is considered positive while distance to the left or down is considered negative. Greater distance indicates greater quantities. As will be seen, this simple convention (analytical geometry) has had a very large impact on our ability to correctly understand our world.

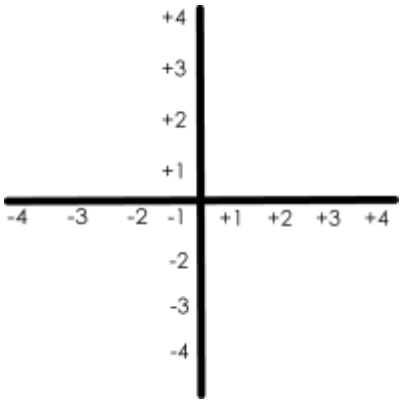


Figure 11.6 Cartesian coordinates. Numbers increase with distance from the center point or origin. Positive numbers are to the right and up while negative numbers are to the left and down.

b. Space as Characterizing Group Data

Groups contain more than a single instance can be complex and therefore can be quite difficult to describe. Several ways have evolved of comprehending and depicting the information in a group of measures.

A tally graph indicates the number of occurrences or the frequency of each value by the number of marks above that value on the abscissa. The height of the stack of marks for that variable therefore also indirectly indicates the frequency of that variable. The total number of marks or asterisks in all columns then indicates the total number of occurrences. The ratio of the number of asterisks in any one column to the total number of asterisks in all columns indicates the relative frequency of that kind of asterisk occurring. For example, if there were a total of 100 occurrences, and 11 were of the specified type then 11% would then be of that type. Continuing this line of reasoning it can be seen that if things continue going like they have been you can predict that 11% of the future occurrences will also be of that type. A tally distribution therefore depicts, that of the total number

of occurrences, 1) how many were of a particular type, 2) what proportion were that type, and if things continue as they have been, 3) what proportion will be of that type in the future (i.e., the probability of that type occurring).

The same reasoning applies to other ways of depicting grouped data such as bar graphs, histograms, polygons, and frequency distributions. Space is used to represent important attributes. A common convention is to use height or the ordinate to indicate frequency, and the distance to the right or left or the abscissa to indicate some other dimension. In the behavioral sciences, the ordinate (***y***) is the dependent variable value, while the abscissa (***x***) is the independent variable value. (The word "acrossissa" can be used as a memory aid. It is almost the same as abscissa and across means back and forth and contains the word cross or ***x***.)

In these cases, the height or the ordinate indicates the frequency of that variable. The total area represents the total number of occurrences. The relative area of one part of the histogram or polygon to the area of the whole histogram or polygon represents the relative frequency of an occurrence of that particular event. This ratio also represents the probability of that particular event occurring in the future if things continue as they have in the past.

A function need not be peaked in the middle as in the illustration; there may be multiple peaks or none.

i. Tally Graph

Instances can be tallied and then depicted as one mark per unit in a figure as is given in Figure 11.7.

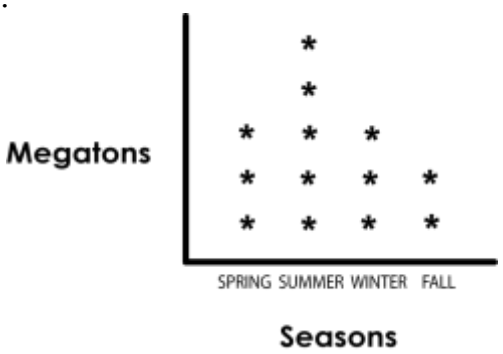


Figure 11.7 Megatons of chlorophyll in North America as a function of season. Each asterisk depicts one megaton.

In Figure 11.7, the values for each season are indicated by the number of asterisks; any mark would serve equally well.

The values are also indirectly indicated by the height of the columns. Numerical data can be represented abstractly, i.e., the ordinate or distance up the ***y***-axis can represent an arithmetic value as shown in Figure 11.8. For example, the amount of chlorophyll in North America for each season can be represented by the vertical positioning of a single "*" above each value along the *x*-axis in a figure.

Figure 11.8 Megatons of chlorophyll in North America as a function of season. The height of each asterisk along the y-axis depicts megatons.

The figure above (11.8) depicts the tons of chlorophyll in North America for each season in one year with only the height of the asterisk indicating the number of particles for that season.

There are two classes of figures that use this columnar form of representation. They are a "bar graph" and a "histogram." They are differentiated in terms of what the abscissa represents.

ii. Bar Graph

A nominal (e.g., eye color), ordinal (e.g., finish order in a race), or discrete or discontinuous ratio variable (e.g., family size) must be depicted with a bar graph. A bar graph does not imply intermediate values. There are no football players with number 66.5. There are no families with 2.5 children. There is no one of size imperial and a half. The height of the bar represents the quantity of the variable represented up the *y*-axis (Figure 11.9 below).

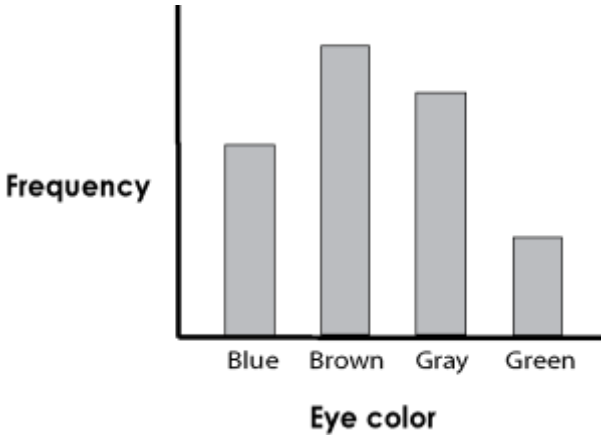


Figure 11.9 Frequency of eye color in North America arranged in alphabetical order.

(1) Nominal Values in Bar Graphs

If the axis is nominal, then the categories along the abscissa or *x*-axis can

appear in any order. Therefore, in addition to no intermediate values, no statements concerning "trends" can be made. Trends cannot occur across a nominal scale because there is no systematic relationship between the categories whereby the categories could be arranged in "order." Trends require ordinal, interval, or a ratio scale across the *x*-axis. The axis in a nominal figure could be rearranged to "prove" any trend a foolish person wanted to imply.

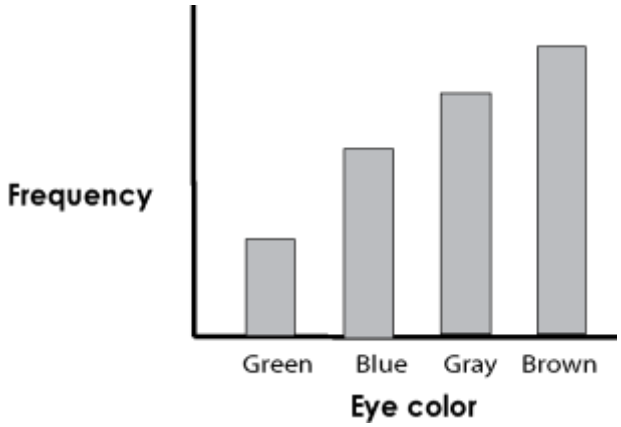


Figure 11.10 Frequency of eye color in North America, arranged to imply an increase to amateurs.

The order of the bars is arbitrary in a nominal data set. By rearranging the order of the bars, we do not show the eye color is normally distributed in Figure 11.9, increasing in Figure 11.10, and decreasing in Figure 11.11. An unscrupulous (and foolish) researcher could present Figure 11.10 or 11.11 and could assert that eye color was increasing or decreasing. Other than saying there are more brown eyes and fewer green eyes, what does it mean to say that eye colors are increasing or decreasing? Wasn't more brown than green equally well illustrated in Figure 11.9?

Figure 11.11 Frequency of eye color in North America, arranged to imply a decrease to amateurs.

(2) Other Than Nominal Values in Bar Graphs

If an ordinal, or discontinuous interval or ratio set, is depicted in a bar graph, then the separated bars must be placed in order. In that case, position along the *x*-axis does indicate an ordered dimension.

iii. Histogram

The histogram is used to depict continuous numbers such as height and weight and implies an ordered set and values between the categories listed along the ***x***-axis. The bars in a histogram are continuous or are drawn together, centered over their *x*-axis value (e.g., Figure 11.12), whereas those in a bar graph are separated (e.g., Figure 11.9). Values are available between bars in a histogram (e.g., between summer and winter). Secondly, because order is fixed, it is meaningful to talk about trends in a histogram.

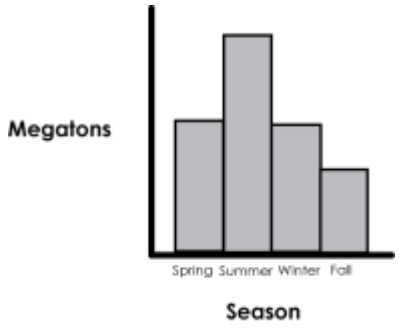


Figure 11.12 Megatons of chlorophyll in North America as a function of season depicted as the height of a bar.

iv. Frequency Polygon

A point may be placed above each category along the *x*-axis at the height of the bar for that category. Clearly the points would represent the same information as the bars as was shown in Figure 11.8. If the points are in the center of each category a line can be drawn to connect them. The line then defines a frequency polygon. The frequency polygon implies quantities that would be appropriate for intermediate categories along the ***x***-axis. Therefore, you may construct a frequency polygon from a histogram but may not construct one from a bar graph. Nominal or ordinal data may not be presented as a line graph because it would imply information about the data that was not correct. If you were keeping track of how many people were ordering each meal at a Chinese restaurant, then plotting with a frequency polygon would imply you had a number for how many people were ordering meal number 19.5.

Figure 11.13 Megatons of chlorophyll in North America as a function of season depicted as a point which designates the height on the y-axis. The points are connected with straight lines.

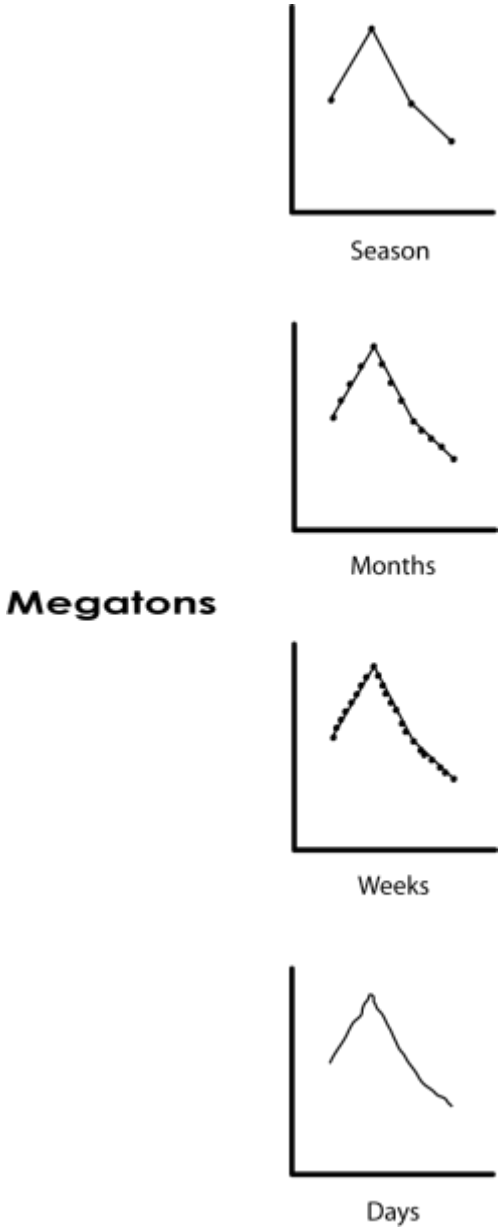


Figure 11.14 Megatons of chlorophyll in North America as a function of successively smaller time units along the x-axis. The y-axis value of each unit is designated with a point, and the points are connected with straight lines.

As can be seen in Figure 11.14, it is clear that frequency polygons can be made with very small spaces between each data point (e.g., each day in a year). In each case, however, straight lines connect those data points.

v. Frequency Distribution

Alternatively, the amount of chlorophyll can be measured in infinitely fine categories with each category being directly continuous with the next until a continuous curve or frequency distribution results (Figure 11.15).

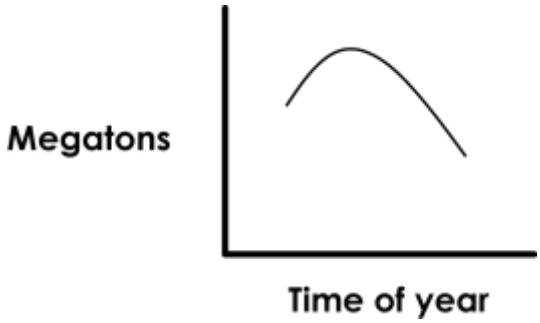


Figure 11.15 Megatons of chlorophyll in North America as a function time. The y-axis value of points along the continuous function designates the megatons of chlorophyll in that instant of time of year.

The height of the curve above any point on the ***x***-axis represents the frequency of that particular event, just as the height of the column had represented the frequency of the event in the bar graph and histogram, and just as the number of asterisks had represented frequency in the tally record. The other relationships hold as well, in the case of the frequency distribution however you cannot meaningfully talk about the probability of an event represented by a single bar because the individual bars are infinitely small. Where a histogram allowed you to choose all the data for April by selecting a single bar, a frequency distribution requires that you specify all the data from one yoctosecond after midnight on March 31 to midnight April 30, i.e., specify the limits of the "bar" you want. One speaks of the frequency of all events contained between Point A and Point B on the ***x***-axis, where A and B can be any position along that axis. A histogram has pre-selected points A and B. Note that less and less interpolation is necessary to determine a *y* value for an intermediate *x*-axis value as the bin size gets smaller until no interpolation is necessary when the function is continuous. It is important to note that a frequency distribution is not necessarily a Gaussian or normal distribution.

Histograms, frequency polygons, and frequency distributions can't be used to depict data that is discontinuous. In that case, continuous functions would misrepresent the reality. A continuous frequency polygon misimplies that family size could be 2.1679 or a Chinese dish labeled 19.38675 exists and that data is available for the impossible category.

c. Conceptual Follow-Up: Information and Grain in Graphical Presentations

In graphing there is also the case where the category exists but there may not be any data in the category. On the other hand, we can take finer and finer slices of time and calculate the amount of chlorophyll in North America in each yoctosecond throughout the year (which is why chlorophyll was chosen as the dependent variable in the example), all data sets do not have a continous property.

For example, if the number of pecks in each 1-minute bin across a 1-minute fixed-interval schedule were plotted (i.e., there would be only one data point for the entire interval and would be the total number of pecks in the interval), unfortunately, we would find that the 1-minute bin failed to represent the increasing response pattern across the fixed-interval schedule. We may want to know how behavior changed across the 1-minute interval by looking at behavior across the interval with a finer grain. As we successively halve the bin size and plot the results across the 1 minute FI, we would get better and better representations of the actual behavior. For example: two bins of 30 seconds each; then four bins of 15 seconds each; then 60 bins of one second each; then…. But at some point, the bin size would become too small. Eventually we would have a series of bins with no data followed by an occasional bin with a 1, when we got down to looking at pecks per consecutive millisecond. This loss of usability with increasing resolution is like zooming in on a digital picture, at some point the image pixilates and further enlargement is useless.

This leads to two realizations: 1) there is an optimum *x*-axis scale for discontinuous data such as key pecks and, 2) frequency polygons and frequency distributions make inferences and extrapolations. What appears as a steady increase in rate at one resolution is revealed to be very choppy at a much finer resolution.

4. Quantifying Group Data

The quantification of group data has had an enormous impact on improving the reliability of data. Part of this gain was due to the choice of dependent measures such as pecking rate which provided sufficient data, and secondly, on the development of numerical and graphical procedures which characterize the data.

a. Central Tendency

Measures of central tendency (e.g., mean, median, and mode) specify a value that can be taken as the ***x***-value that is representative of all the values in the distribution in some way. Central tendency specifies how far that representative value of the distribution is out from the origin along the x-axis. The difference between various measures of central tendency results from the difficulty of a single formula providing a meaningful single summary value for all possible distribution shapes and for all possible purposes.

For example, the mean income for families in the United States has been

increasing for a decade. However, that cannot be taken to indicate that all families are earning more. Figure 11.16 illustrates what is actually happening.

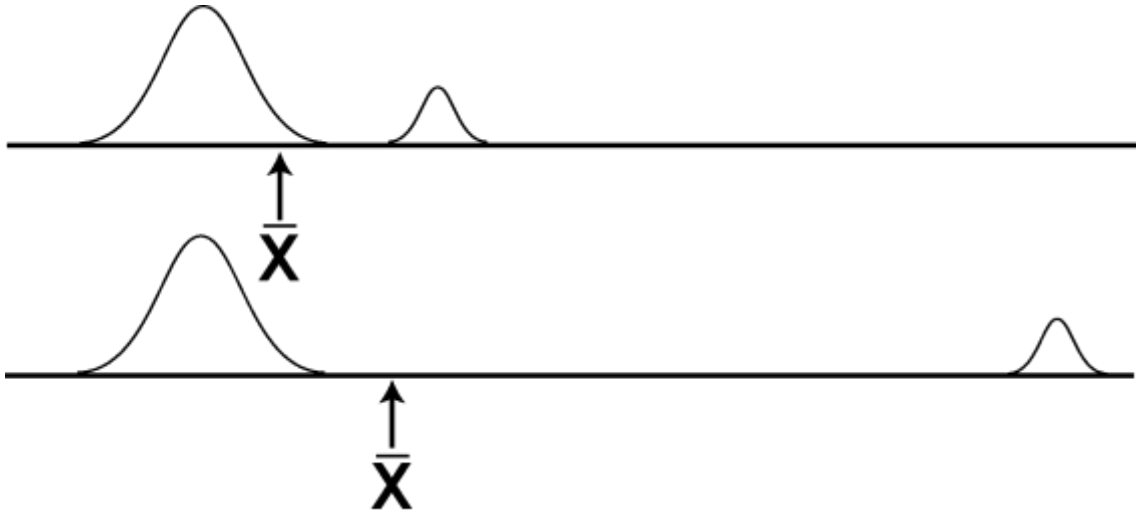


Figure 11.16 Figure illustrating that a change in outliers (in this case, the extremely wealthy) can change the mean while the majority of the data set is unchanged.

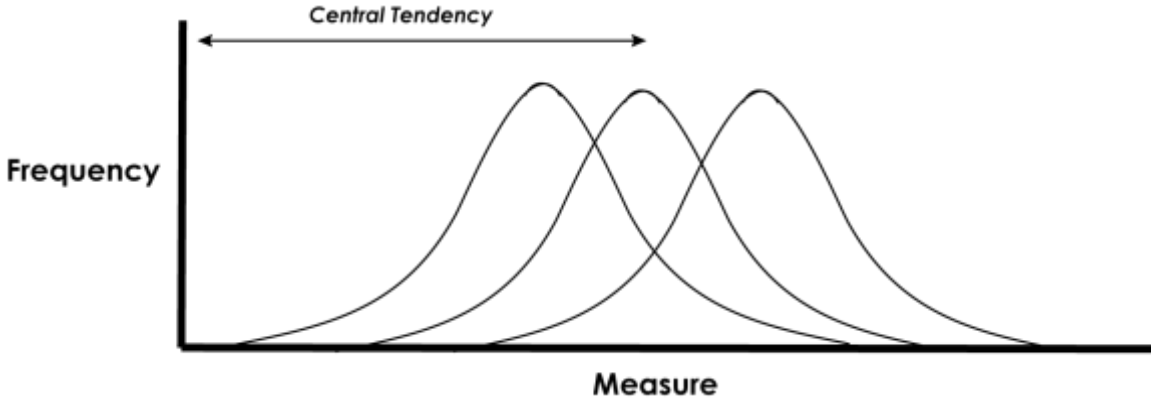


Figure 11.17 This frame illustrates three distributions with successively larger means but that are otherwise identical.

b. Dispersion

Measures of dispersion indicate how the values within the distribution differ from one another (e.g., the standard deviation or variance). Distributions that differ with respect to their dispersion are spread out or bunched together to a greater or to a lesser degree. This measure typically specifies how far the elements as a whole are from the mean.

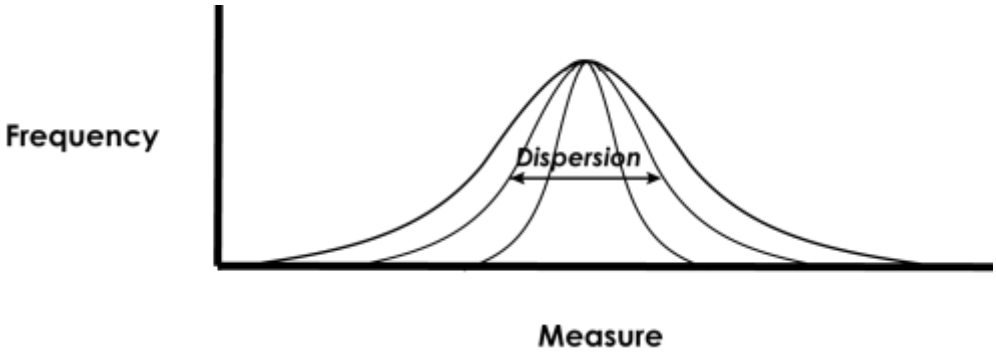


Figure 11.18 This frame illustrates three distributions with successively larger standard deviations but that are otherwise the same.

c. Shape of Distribution

Distributions are not always uniformly symmetrical and Gaussian. Distributions can be tipped to one side or the other to a greater or lesser extent, or can be more sharply peaked or flatter. Typical measures of the shape of a distribution are kurtosis (flatness or squatness) and skew (tip).

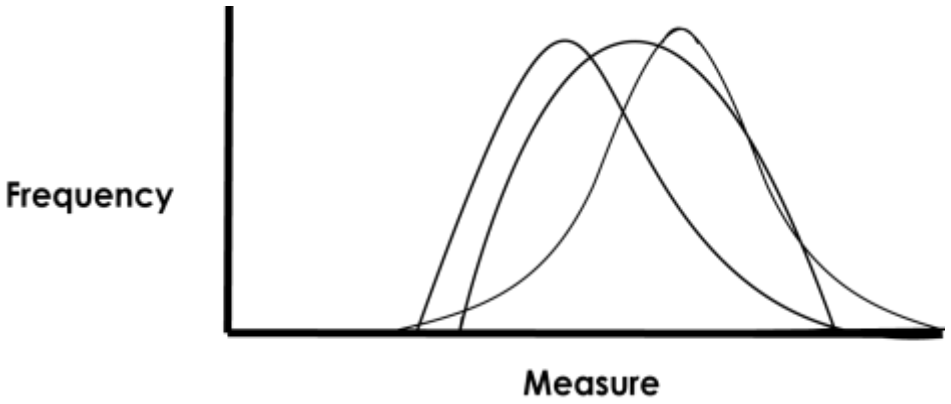


Figure 11.19 This figure illustrates three distributions with different skews.

C. Maximized Variability Contained Within Rule

The third major guideline useful for maximizing reliability, is maximizing the diversity of measurement. If you make a statement of a functional relationship based on only an extremely narrow specific group of subjects, kind of apparatus, or procedure it is possible for it to be altered by even a small change in some variable. Statements of wide generality that fit many situations are less likely to be disrupted by unforeseen events. More broadly based statements are more reliable. For example, schedule effects (e.g., FI scallop and stable VI rate) occur across virtually every species, every operant, and every reinforcer tested. Because of the enormous variability contained within the rule, the likelihood that some

new type of subject will be different is very low. As a second example of broadly based rule, reinforcement works across species, across behaviors, and across type of consequence; it is extremely unlikely to fail in a new situation.

D. Appropriate Research Technique for Given Subject, Apparatus and Procedure

1. Familiar Context

Unfortunately, all possible variables are not reported in every research paper. Some variables are not made explicit because they are thought to be obvious and well known, or are common to normally accepted research practice, or to everyone's research style. People familiar with a particular area are likely to know through experience what to control as a matter of professional research practice even though every detail does not appear in print. This absence is not because of carelessness or ignorance but rather the recondite nature of professional research. Papers are intended to efficiently communicate to professionals rather than to educate beginners. Reliability can be increased by being aware of the important variables in a situation that are not explicitly pointed out. Apprenticeships, internships, and practica for students in a field are extremely important for this reason.

2. Procedurally Accurate

If you document what you do carefully and follow the procedure explicitly and if your measurements are valid then it is likely that someone else following the same directions will obtain the same results. If you do not document what you did correctly or had invalid measures, it is unlikely that their cake will turn out, when they use your recipe. It's also obvious that any statistical tests of reliability or quantitative index must be calculated correctly and the data must meet all the assumptions of the calculations.

3. Technologically Sophisticated

A technologically sophisticated experiment exerts as much control over confounding variables as possible to minimize their impact. It also measures variables in the most sophisticated way possible to maximize the accuracy and precision of the obtained measures. Higher technology provides better tools to enable correct assessment of the actual controlling variable and provides the power to reproduce the effect by accurately creating or recreating the controlling conditions. Using a scale to measure weight is more reliable than a subjective estimation. Data generation, storage, and analysis that is automated and completely computerized and seamlessly integrated or "untouched by human hands" is less likely to contain errors than is research that requires manual data recording and data entry. This is especially the case when any errors are eliminated by correcting the steps in the automation.

4. Large Signal-to-Noise Ratio

An extremely strong effect is likely to recur or be reliable, whereas a very small effect is more likely to be overshadowed by noise, or to have arisen by chance or be an artifact in the first place. You can obtain large signal-to-noise ratios by choosing to study strong effects, by using strong treatments, or by reducing the noise in the experiment. The ramifications of signal-to-noise ratio with respect to detectability have been covered in chapters 3 and 5 and are discussed again in the next chapter.

Recall that the ratio of the magnitude of the treatment effect to the magnitude of random variations in the behavior or what is labeled effect size is used to determine the likelihood that the effect was due to chance.

5. Correct Elimination of Confounds or Correct Experimental Design

In order to draw the correct conclusions from the results of research, every single confound must be eliminated to assure that only the treatment is the difference between the two conditions. Experimental design is the specific procedure that guarantees that you have "subtracted out" or "cancelled" every potential alternate explanation for an effect.

The absence of confounds in research is labeled internal validity. Without it, your results could vary as a function of the things you have failed to control. Any variable that you didn't explicitly control could be the actual cause of the effect and once there is any doubt that the treatment was the cause, your experiment is useless. Confounds are all the worse because most often, they are not apparent until it is too late.

a. Single-Subject Designs

Single-subject designs most often establish a baseline performance without the treatment then add the treatment. After a stable sample of asymptotic performance, the subject is returned to the baseline conditions.

The difference in the performance under the baselines and treatment can be attributed to the treatment 1) only if the difference between the baseline conditions and the treatment conditions are substantially greater than chance; 2) only if the baseline behavior is recovered thus indicating no parallel process (such as aging) and 3) the whole cause and nothing but the cause is isolated and identified as "the treatment."

b. Group Designs

With group designs, the difference in the performance in the two groups must be greater than could be attributed to chance for the treatment to be considered effective. The measure of error or chance is the amount of variance in the difference between the means of the two groups if the two groups had received the same conditions. A necessary prerequisite for this to be true is that the two groups are effectively identical. Any initial difference between the groups may result in a

significant confound. For example, if one group had many more undernourished people than the other, then the difference between the groups at the end of the experiment could be due to the difference between the groups at the beginning of the experiment rather than the difference cause by the treatment. As previously discussed in Chapter 3, group designs have many flaws and tend to be avoided by behavior analysts.

Several procedures have been developed to eliminate or reduce the confounding effect of the initial difference between the two groups. Each of the techniques below are ways to try to assure that the only difference between the results of the treatment condition and the control condition is due to the treatment of interest rather than a difference in the two groups themselves. Each of the subsequent correction procedures are attempts to assure that only the treatment can be the cause of the difference in the dependent measure between the two groups, if it is not simply chance.

i. Elimination

Obviously, the best method of dealing with confounding variables is to remove or eliminate anything that makes the two groups different before the research starts. In that way, your dependent measure will not "bounce around" as elements that you did not control exert unpredictable amounts of control. Elimination is a simple way to assure that the two groups are exactly the same. If you were measuring the effect of a short period of vigorous exercise on IQ, and found that some people were taking the test while drinking coffee while some did not drink coffee and that the two groups could differ with respect to how much coffee they drank, you could methodologically eliminate the confounding variable by not allowing anyone to drink coffee during the test.

Alternatively, you could eliminate the difference caused by the coffee by having everyone drink coffee, or by considering the coffee drinkers separately from the nondrinkers in your analysis of the results. You could also attempt to eliminate the effect statistically by subtracting the effect that the coffee had on the IQ test from the scores of those who did drink it. This last correction requires, of course, that you know the effects of coffee on each IQ score.

ii. Pair-wise Matching

A different method of removing potential confounds is to equalize the effect of the confounding or extraneous variable on the different groups. If your research is a groups design, you could ensure that for each person in the experimental group that drank one cup of coffee there would be a person assigned to the control group that also drank one cup of coffee. For each person that drank two cups of coffee in the experimental group there would be a person that drank two cups in the control group, and so on.

iii. Explicit Group Balancing

You could also explicitly balance the two groups to remove the differential effects of a confound. This balancing procedure would be analogous to having two basketball teams play several games switching players after each game until they ended a game in a tie. If the next five games all ended in a tie, you could presume that the groups were equal regardless of any other similarities or differences in the characteristics of people on the two teams. This procedure would explicitly balance the groups with respect to basketball playing ability. You could then implement some treatment on one of the two groups which was thought to affect basketball playing such as a motivational speech before the game. If the two groups differed after the treatment, you could infer that the treatment was the cause.

iv. Balancing by Theoretical Notions

There are occasions when equalization or explicit balancing to remove confounds is not applicable or possible. In that case, you can still try to balance the two groups based on what you think should make them be equal. This differs from the previous example because in this case you only believe that that procedure will balance the two groups rather than explicitly balancing them. Most frequently this takes the form of counterbalancing the groups by, for example, assigning the best and worst individual to one group and the two middle individuals to the other group.

A problem with balancing by this latter theoretical notion is that a "linear" effect of the confound is usually assumed, e.g., it is generally assumed that the average of the middle two intensities of each confound is equal to the average of the outer two. For example, in the series of 1, 2, 3, and 4, the mean of 1 + 4 or 1 + 4 over 2 is equal to the mean of 2 + 3 or 2 + 3 over 2. The problem is that a linear solution may not be appropriate as when the original scores are 1, 2, 3, and 9. In that case, the average of the outer two does not equal the average of the inner two.

In the explicit balancing example, the distribution of coffee drinking in each of the two groups is the result of the empirical process of balancing whereas with balancing based on theoretical notions, we sort subjects into groups that we have some reason to believe are on average equal, but for which we have no proof. We have no evidence that the average of one and four cups of coffee is the same as the average impact of 2 and 3 cups of coffee.

v. Balancing by Randomization

Finally, members of a population can be randomly assigned to two groups in order to remove confounds. In this way, the groups will tend to be equalized by the action of chance (given about 30 or more elements). Amazingly enough, random assignment will tend to (but not necessarily) equate any number of variables simultaneously. In fact, it will equate variables that you are not even aware of. Any other assignment method requires perfect knowledge of potentially confounding factors and a very extensive task of determining how to assign

individuals to the two groups such that the overall groups are equated.

In point of fact, most inferential statistics are designed to assess the likelihood of two groups of individuals selected at random differing by the obtained amount. For that reason alone, it is advisable to select groups by random assignment if the subsequent statistical treatment assumes it.

6. Correct Application of Analytical Technique "Meeting the Assumptions"

The statistical treatments that are applied to the data generated by research require that certain assumptions be met. For that reason, research that will be analyzed by statistics must be designed with its subsequent statistical analysis in mind. A particularly troublesome problem is the use of the correct statistic for the type of variables used in the research. See "The Amount of Information Retained in Measurement" section in the present chapter.

The level of reliability specified by a statistical test is meaningless if done on data that violate the assumptions of that statistic. For example, if ordinal data is analyzed by a statistic designed for ratio data, then the obtained level of significance is meaningless. If the statistic used to assess the reliability of an effect presumes a normal distribution of scores and the obtained data are not normally distributed, then the obtained level of significance is meaningless. This would be similar to a sporting record obtained in a situation that violated the assumption of the sport. For example, an NFL quarterback who gains 700 yards in a single game by playing against high school students has set no record.

E. Use of a Revealing Analytical Perspective

1. Correct Specification of Controlling and Controlled Variables or Relevant Independent and Dependent Variables as Axes

The chosen dependent variables should be viewed in terms of dimensions that are actually controlling those changes. For example, little long-term, real consistency would be obtained if a psychotherapeutic method were evaluated in terms of the shoe size of its recipients. The apparent success of the therapy with children and its lack of success with adults would be spurious. Even though shoe size tends to increase with time and therefore indicates increasing psychological health in children helped by the therapy, it also incorrectly indexes the health of many clients who are getting worse or showing no change. Psychotherapy should be judged in terms of some consensually validatable and relevant dependent measure such as the percentage of successful social interactions or whatever is agreed to be what psychological health means.

The correct or valid identification of factors that are influencing the dependent measure makes sure that relevant but unrecognized variables will not be inadvertently changed or left out during attempted replication. If the actual controlling variable was not correctly specified, it may not be included in an attempt to replicate. The original finding will, as a result, be unreliable. Replication by other laboratories is essential for this reason. This external

validation assures that the relevant factors have been specified as the independent variable. It is unlikely that the two laboratories or researchers have the same confounds.

For example, take migrating birds as an example. Suppose that precipitation was mildly correlated with the seasons and therefore the duration of daylight. A researcher may claim that rainfall caused migration when in actuality it was the light cycle. Research into the relationship between rainfall and migration would send researchers down a blind alley.

2. Correct Level of Analysis or Transformation of the Data

At times, there is overall consistency in data while there appears to be little local consistency, or vice versa. This is the "forest-trees" problem. A comparison of whole forests may show consistent effects, even though a comparison of each tree is confusing or vice versa. Viewing the data within a broader or narrower context may increase reliability. This issue was presented earlier in the context of "the grain in graphical presentations" or small bin analysis. Additionally, rescaling the data with a transformation such as a log transformation may allow the orderly nature of the data to be more apparent.

Whether or not consecutive measures of the same thing have the same value or not is affected by the measuring instrument. An instrument that is extremely coarse will provide measures which differ very little and which are therefore extremely reliable. For example, if you measured your weight on a scale for tractor-trailers you would find that you always weighed the same even after very large meals or while carrying scuba weights. The instrument would provide data that was extremely reliable in that it was always the same. Unfortunately, it would be of little use for dieting because it would not reflect one or two pound changes. At the opposite extreme, an instrument which is extremely fine will obtain data which is very sensitive to very small changes but which is not at all reliable because it changes as you breathe and as dust falls on you. It does not emphasize the similarity of the events. A compromise must be struck between ridiculously gross measures which are very reliable yet are not useful because they do not detect meaningful differences; and ridiculously fine measures that are not useful in that they vary so widely that they mask similarity.

F. Insightful Tactics

A researcher can maximize the reliability of their findings by correctly choosing questions or structuring the situation to dramatically expose the controlling variables. This is the art of good research. It is the degree to which you can identify a clear boundary condition that varies from one category to the other when you change the independent variable. For example, when trying to guess letters in a game like "Wheel of Fortune," some letters are more likely to be right than others, but you must be aware of the letter frequencies in English before you can use this insightful tactic. This is the reason reading the research literature is absolutely essential and by far the most productive thing you can do.

CHAPTER 12

Optimization of Knowledge Gathering / Problem Solving (Research): Detectability

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I. Maximization of Analytical Detectability

A. Conceptual review: decision theory and graphical representation of signals, noise, and decision criteria
B. Decrease criterion stringency to decrease misses
C. Increase signal-to-noise ratio to decrease misses
    1. increase the magnitude of the signal to increase signal-to-noise ratio
        a. graphical illustration of increasing magnitude of signal
        b. methodologically increase magnitude of signal
            i. subject
            ii. apparatus / setting
            iii. procedure
        c. mathematically increase magnitude of signal
    2. decrease the magnitude of the noise to increase signal-to-noise ratio
        a. graphical illustration of decreasing magnitude of noise
        b. methodologically decrease magnitude of noise
            i. subject
            ii. apparatus / setting
            iii. procedure
        c. mathematically decrease magnitude of noise

II. Maximization of Paradigmatic Detectability

A. Conceptual precursors
    1. conceptual precursor: goals in maximizing paradigmatic detectability
    2. conceptual precursor: decision making in data analysis
B. Paradigm choice in TSD framework
    1. example paradigmatic decision
    2. deviation of phenomenon and paradigmatic limits
    3. deviation of phenomenon and paradigmatic gain/risk
C. Paradigm choice and reduction in the complexity of explanation
    1. if equal local complexities of explanation for all phenomena
    2. if differing local complexities in explaining various phenomena

D. Decision point or tipping point optimization for paradigm revolution
E. Strategies for maximizing paradigmatic detectability
    1. sloppy use of the “paradigm” or eclectic framework to maximize paradigmatic detectability
    2. conceptual precursor: graphical representation of paradigm choice
    3. decrease criterion stringency to increase detectability of paradigm
    4. increase signal-to-noise ratio to increase detectability of paradigm
        a. increase compellingness of the new paradigm to increase signal-to-noise ratio
        b. demonstrate failures in the existing paradigm to increase signal-to-noise ratio

CHAPTER 12

Optimization of Knowledge Gathering / Problem Solving (Research): Detectability

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The previous chapter detailed how to optimize research with respect to the generation of repeatable findings: an essential characteristic of all elements within science. The present chapter will detail how to optimize the research with respect to its ability to detect true events or processes even when those events and processes are subtle or of small magnitude.

I. Maximization of Analytical Detectability

Simply put, research must be as sensitive as possible and detect the weakest possible functional relationship, and the researcher must do everything they can to make that the case. From the paradigmatic perspective, the theory should make the paradigm capable of explaining very subtle or very unusual effects.

Detectability refers to an ability to correctly identify events that are non-chance even when those effects are very small or subtle. An emphasis on the detectability or power of a test (the avoidance of misses) generates the opposite pressure to that of an emphasis on reliability (the avoidance of false alarms).

The issue is well illustrated by a cowardly and a macho camper on a windy night in bear country. If while asleep they are awakened by a sound, then that sound could be a bear or not, and they could run for their life or not. The more extreme their criteria for judging that the event is a bear such as only if the sleeper hears roaring and trees splintering and see paws coming through the tent then the less likely they will mistake wind for a bear. Reckless Rick would have a high criterion such as that because he is quite macho and would be humiliated if he ran from the wind. Unfortunately, having such a high criterion for when to run for his life will also make it more likely that he will overlook subtle but nonetheless real bears (i.e., Reckless Rick will fail to run away when a bear is simply walking up to the camp quietly). His criterion does not have much detectability. Charlie Chicken on the other hand will run whenever even slightly odd noises occur. While it's unlikely that Charlie Chicken will miss noticing a bear, he will certainly miss a lot of sleep. The good thing to say about Reckless Rick's criterion for when to run

is that if he is running, it's surely a bear. The good thing to say about Charlie Chicken is that if there is a bear, he is surely running.

If you are extremely conservative when deciding if an event is an important discovery, it is likely that you will miss some important phenomena that are really there, but that are only subtle. Your decision mechanism will have high reliability but poor detectability. The best solution to the problem of having both reliability and detectability is to increase the signal-to-noise ratio so that the signal stands out against the background more. This can be done by increasing the magnitude of the effect or decreasing the background noise.

By simple reasoning, it can be seen that several things can be done to maximize your ability to realize when you have a meaningful research or therapeutic discovery even when the effect is actually small, i.e., to increase the detectability of your procedures.

A. Conceptual Review: Decision Theory and Graphical Representation of Signals, Noise, and Decision Criteria

The logic of this entire chapter depends on a decision analysis framework. If you are not now fully comfortable with it, take a moment at this time to review that material in Chapter 3.

Recall also that the actual decision-making machinery is fundamentally the same in Behavior Analysis and in null hypothesis significance testing decisions.

- there are baseline or control measures that vary
- there are treatment effects that can change the measured variable, and those changed measures can vary
- there is some amount of change or point beyond which that change is so unlikely to be chance that the researcher is willing to declare that a true effect occurred which may or may not be a correct decision
- less stringent criteria will result in fewer misses but also more false alarms, while a more stringent criterion will result in fewer false alarms and more misses
- the actual decision criterion for when to decide "true effect" must be based on the relative cost of each type of error

A concrete example requires a single example such as the figure below. If you can, try to see that no matter where the signal distribution is along the *x*-axis to the right or to the left of the noise distribution, or how wide or narrow either distribution is, or what the shape of the distributions are, all the issues in the following section are the same. The leftmost distribution in the upper section of each figure is as a reminder that the signal distribution can be weaker than the noise or baseline distribution as well as stronger. All examples will be based on stronger signals against the average.

B. Decrease Criterion Stringency to Decrease Misses

The first way to increase the detectability of a procedure is to decrease the criterion stringency for claiming a true effect. That is to say, how much of a change must the treatment make before claiming that the treatment worked. The stringency of the criterion for claiming an effect (a bear) can be decreased (e.g., from A to B in Figure 12.1). In this case, you would then be more likely to claim a true effect when there actually was a true effect (fewer misses).

Note in the lower portion of the figure that to the left of the axes the size of misses decreases as the criterion changes from A to B. Note to the right of the axis that the size of false alarms increases as the criterion changes from A to B. compare the distribution segments in the lower portion of the figure with the original distributions in the upper portion of the figure. As a result of the change in the criterion from A to B, you are less likely to make a miss but are also more likely to claim an effect when there is no real effect (more false alarms).

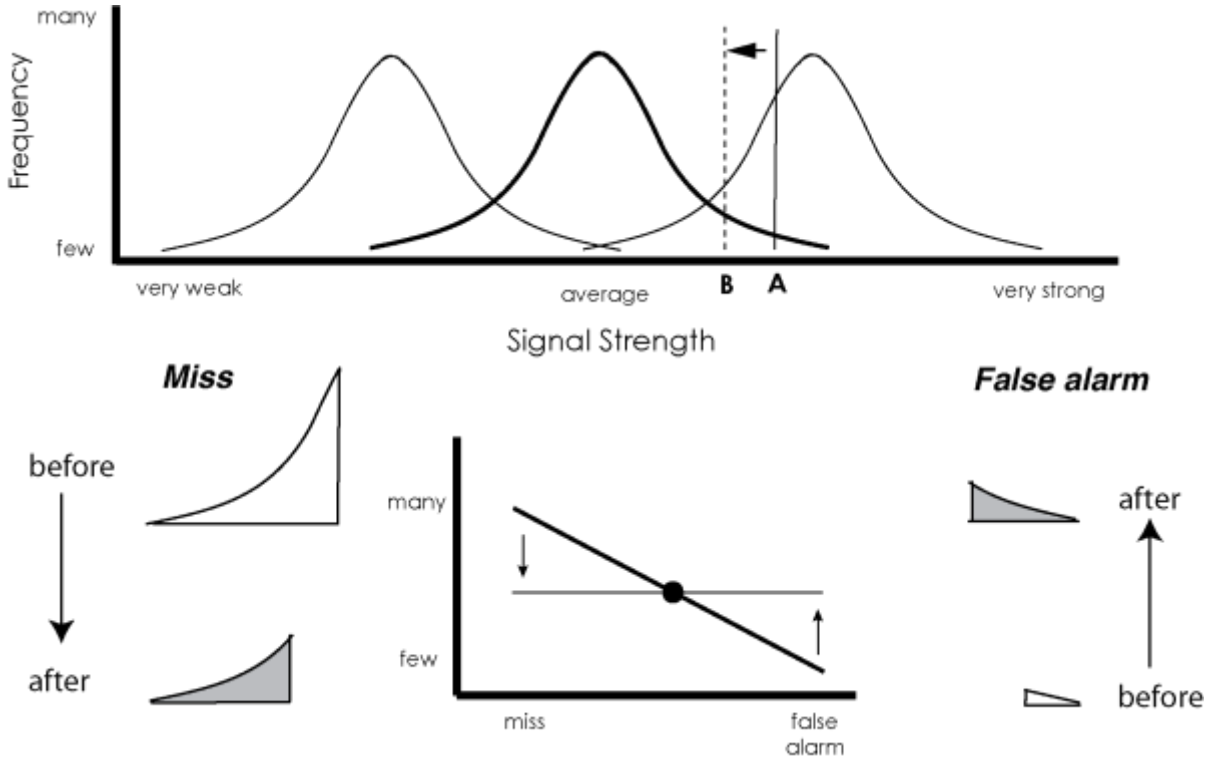

Figure 12.1 The standard format for depicting decision analysis first introduced in Figures 3.11 through 3.21. The upper portion of the figure illustrates a noise distribution in the center of the x-axis with a slightly heavier function. Two of a potentially infinite number of signal distributions are also depicted, one to either side of the central noise distributions. The initial x-axis criterion value along the x-axis is illustrated at "A" with a less stringent criterion illustrated at "B." The central portion of the bottom half of the figure illustrates the inverse relationship between changes in the number of false alarms and the number of misses with a change in criterion. The left and right edge of this portion of the figure illustrates the size of the false alarms (small segments of a distribution to the right), and the size of the misses (large segments of a distribution to the left). When the criterion is set at "A," the open false alarm segment in the lower right and the open miss segment in the upper left. After the criterion is changed, the misses get smaller (lower left) but the false alarms get larger (upper right).

This decrease in the criterion stringency approach is not an entirely desirable approach to decreasing misses because it necessarily increases false alarms.

C. Increase Signal-to-Noise Ratio to Decrease Misses

A second way to increase the detectability of a procedure is to increase the signal-to-noise ratio. Anything that increases the separation of the signal distribution (e.g., the right distribution) and the noise distribution (i.e., the center distribution) is said to increase the signal-to-noise ratio and will increase the likelihood that an effect will be detected at a given criterion of false alarms (i.e., increase detectability).

1. Increase the Magnitude of the Signal to Increase Signal-to-Noise Ratio

The first way to increase the signal-to-noise ratio is to increase the magnitude of the signal. In Figure 12.2 below, this would be moving the right signal distribution further to the right (or the left signal further to the left). The lower segment of the figure indicates that misses decrease and there is no change in the magnitude of the false alarms.

a. Graphical Illustration of Increasing Magnitude of Signal

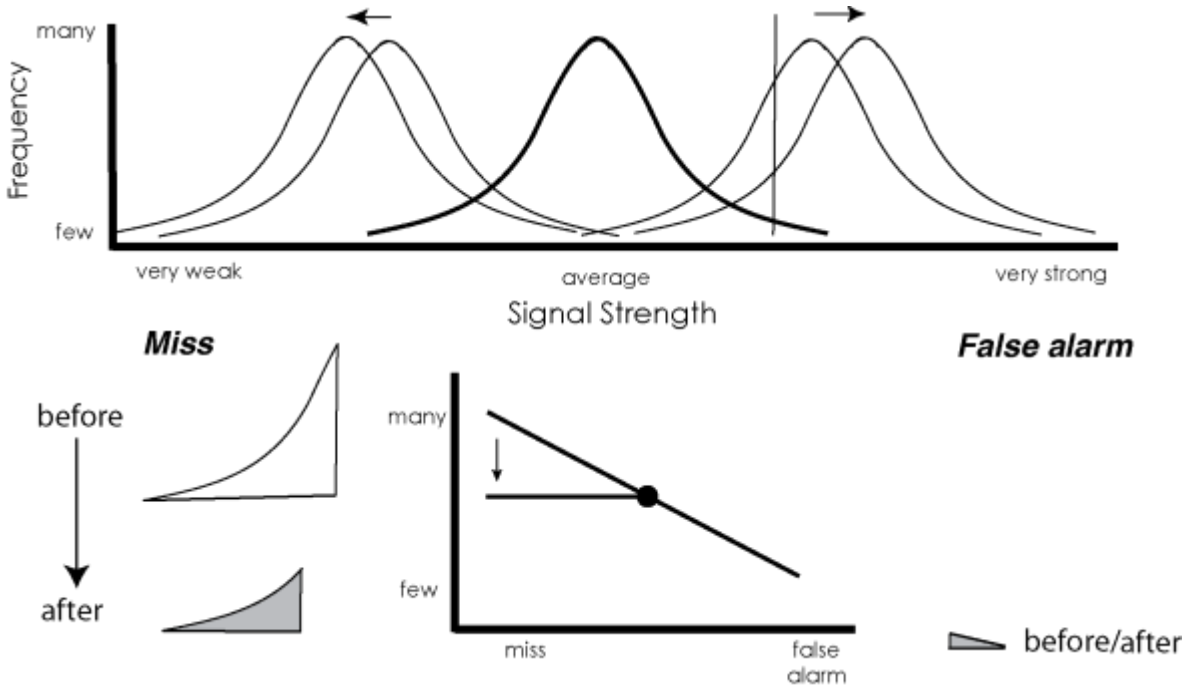

Figure 12.2 The upper portion of the figure illustrates a noise distribution in the center of the x-axis with a slightly heavier function. Two of a potentially infinite number of signal distributions are also depicted, one to either side of the central noise distributions. Two more extreme signal

distributions are also illustrated a bit further out from the noise distribution. The central portion of the bottom half of the figure illustrates how the number of false alarms and the number of misses change with a change in the magnitude of the signal.

b. Methodologically Increase Magnitude of Signal

Behavior analytic research is characterized by a very strong emphasis on methodological solutions to research questions.

i. Subject

Choose subjects that react strongly to the treatment; for example, birds were used to detect poisonous gas in mines because they were very sensitive to the concentration of methane and would react before it was too late for humans to escape.

ii. Apparatus / Setting

Choose an apparatus that is especially sensitive to the dependent measure's reaction to the treatment. For example, choose a setting or develop an apparatus that magnifies the signal. If you wish to hear a visitor at the door during a loud party, make the doorknocker very large because it will increase the magnitude of the signal. In the camping example, hang tin cans around the camp. Anything entering the campsite will make louder sounds. The signal (bear) will make much louder sound than the wind in the trees.

The preceding figure (12.2) illustrates the effect of increasing the signal (bear)-to-noise (wind) ratio by increasing the magnitude of the signal (bear). Whereas under the original conditions, the bear noise may vary from very quiet to quiet as it was walking; by stringing cans around your camp, the bear noises would vary from medium to loud because what had been a foot fall on dirt (very quiet) is now a foot tripping over a tin can (medium). If a bear is approaching, the quietist noise it can now make is the sound of tin cans. If a bear moves at all it tends to be loud enough to hear (amplify or add ten to all scores in the original bear noise distribution). Where earlier you were only able to detect when the bear just happened to step on a dry branch or trip, you can now detect when the bear only moves its leg, because every bear sound is now ten units bigger. What this does geometrically is to move the bear noises to the right by ten. A movement that had been above the 20 on the x-axis is moved to the right to above 30. This gives the appearance of shifting the bear curve up.

iii. Procedure

The more you are "in tune" with the natural laws governing the behavior then the greater the percentage of the whole "true" effect you will be able to control thus increasing the magnitude of the effect. Getting in tune depends on how well you understand the paradigm and how accurately your chosen paradigm describes

nature.

Experimenter finesse is the term for your ability to devise an experiment that maximally illustrates the effect. This goes beyond simply taking advantage of special characteristics of a particularly apt subject and an apparatus that maximally facilitated the effect. For example, in order to find exactly how much a box of candy in 8 hours was worth right now you could test subjects by letting them choose over and over again between money now or the box of candy in 8 hours. Each time the smaller sooner was chosen, you could decrease the amount of money available now. Each time the box of candy was chosen, you could increase the amount of money available now. The result of this titrating schedule would be a fluctuating function precisely specifying how much the box of candy in 8 hours was worth right now, as a function of the elapsing time across the experimental session.

c. Mathematically Increase Magnitude of Signal

The dependent variable could be indexed over a wider time period in order to maximize detectability. Whereas it may be unlikely that a single noise of a particular amplitude is indicative of danger, it is quite a different case if noises of that amplitude occur in a systematic pattern (footsteps, for example). In that case, you should run. You would be able to detect a very quiet bear by sampling information over a wider time period. With a larger sample, you would catch the rare time the quiet bear stepped on a dry branch.

2. Decrease the Magnitude of the Noise to Increase Signal-to-Noise Ratio

A second way to increase detectability by increasing the signal-to-noise ratio is to decrease the magnitude of the noise. In the example graphed below in Figure 12.3, this is narrowing the width of the center noise distribution. In the following example, it is presumed that the goal is to maintain the percentage of false alarms (e.g., .05) by changing the position of the criterion (e.g., A to B).

a. Graphical Illustration of Decreasing Magnitude of Noise

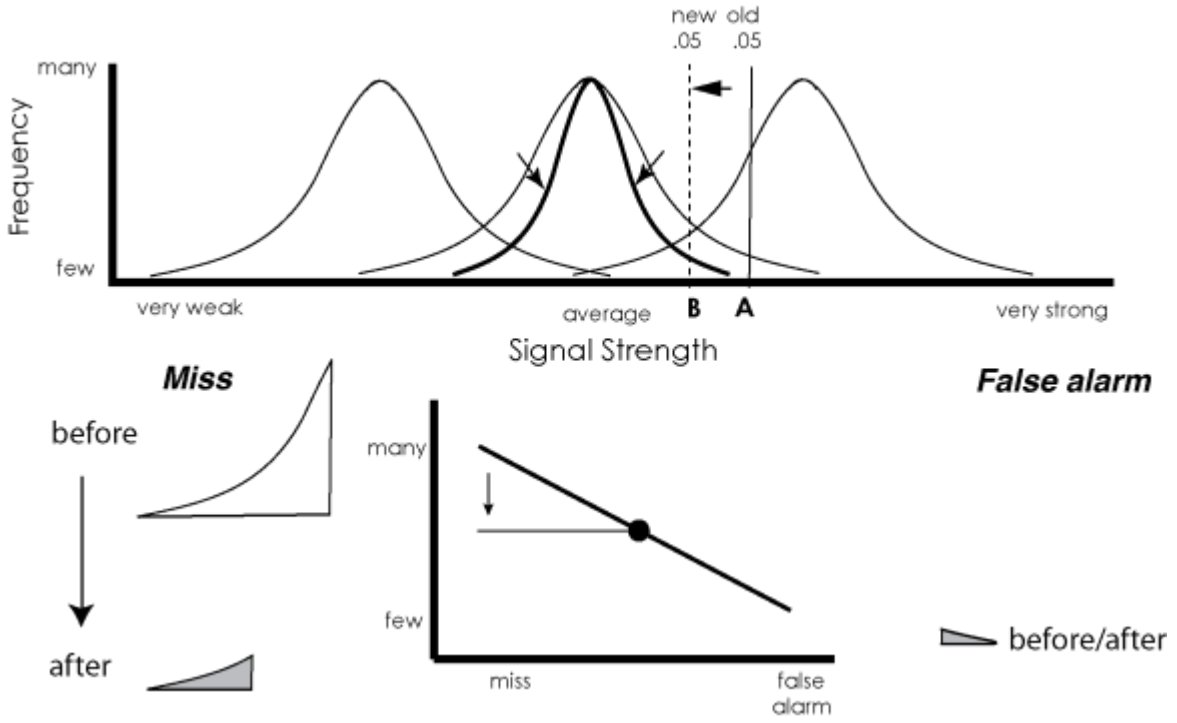

Figure 12.3 The upper portion of the figure illustrates a noise distribution in the center of the x-axis and a noise distribution with reduced variance with a slightly heavier function. Two of a potentially infinite number of signal distributions are also depicted, one to either side of the central noise distributions. The initial x-axis criterion value along the x-axis is illustrated at "A." A criterion that provides the same rate of false alarms for the noise distribution with reduced variance is illustrated at "B." The central portion of the bottom half of the figure illustrates how the number of false alarms and the number of misses change with a change in the magnitude of the noise distribution.

b. Methodologically Decrease Magnitude of Noise

Methodological solutions characterize behavior analytic research.

i. Subject

Choose a subject that shows very little variability in its baseline rate or scores. When rats are used for sensitive assays of behavior, typically only male rats are used because they do not show the behavior variability associated with estrus.

Choose a subject that is especially insensitive to the most likely confounds. For example, if uncontrollable random sounds are making your pigeon do weird things while you're trying to find what your treatment does on a visual task, choose deaf pigeons.

ii. Apparatus / Setting

Use an apparatus which shields against the major confounds. For example, if variability is caused by loud sounds use a totally soundproof chamber. In the camping story, eliminate all the safe things that make loud noises throughout the night. Cut down the limb that rubs on your tent whenever the wind blows. You will then be able to easily hear a bear roar. If you wish to hear a quiet doorbell at a party tell the people who are making noise to be quieter; that is, decrease the magnitude of the background sounds.

iii. Procedure

Run pigeons at exactly the same time every day at exactly the same body weight and run each schedule for very many sessions to assure that the pigeon adapts to every aspect of the procedure. The variations in the behavior caused by procedural variations would then drop to a very low level and the effects of very small treatment effects (signals) would be made obvious.

c. Mathematically Decrease Magnitude of Noise

Average the data over a longer period so that the contribution to the measure of the random noise is very small. If each subject shows day-to-day variations, then take 5-day averages rather than obtaining scores each minute.

Signal averagers are a good example of solving a signal-to-noise problem with the fact that the mean of a random series is zero. If a very low amplitude signal always occurs 100 milliseconds after a light flash but occurs amid substantial random noise, then presenting the light flash over and over while averaging each momentary period after the light flash will reveal the very low amplitude signal. This occurs because at each small-time period after the light flash sometimes the random noise is positive and sometimes it is negative. In the long run the random noise at each moment after the light flash will be zero. 100 milliseconds after the light flash a different thing happens. The background is random plus a small, consistently positive signal. After many iterations, the positive offset will remain while the random noise averages to zero.

The preceding figure illustrates the effect of increasing the signal (bear) to noise (wind) ratio by decreasing the magnitude of the noise (wind). For example, by clearing the area around your campsite of the limbs that make noise in the wind and turning your satellite TV down, the typical sounds around the campfire are substantially reduced, whereas the reliable signal (i.e., the bear) will remain where it is. What this does geometrically is to narrow or squeeze in the noise distribution.

II. Maximization of Paradigmatic Detectability

A. Conceptual Precursors

Note that the following material applies decision analysis, a conceptual framework that may be somewhat new to some of you, to better understand paradigms that are also likely to be somewhat new to some of you. Do not attempt to read the following material without consulting and working through, in detail, the included graphics. The written material is not intended to stand-alone. If you are not fluent with paradigms and decision analysis, take time now to reread those sections in the earlier portion of this text. Paradigms are covered in great detail in Chapter 2. Decision analysis is discussed in great detail in Chapter 3. If that material is insufficient, consult other sources.

1. Conceptual Precursor: Goals in Maximizing Paradigmatic Detectability

Effort must be taken to: 1) paradigmatically account for as much variance in nature as possible so that the correspondence between the obtained data from nature and the paradigmatic explanation is as close as possible, and; 2) encourage as much diversity in methodology as possible in order to extend the paradigm across the broadest range of natural phenomena possible, and finally; 3) on the one hand, consider anomalies between nature and the paradigmatic explanation as important because they could reveal important ways that the existing paradigm could explain them, or on the other hand, they could reveal a fundamental weakness in the paradigm. In either case the new data will increase our ability to explain all data by increasing the detectability of our paradigm even if that requires a new paradigm. Keep in mind however that the new data could be wrong(a false alarm or just noise).

2. Conceptual Precursor: Decision Making in Data Analysis

As you have just seen in the previous sections, all decisions whether they are NHST, BARS, or seat of the pants are based on an explicit acceptance of the trade-off between better detectability (decreasing misses) and better reliability (decreasing false alarms). For example, in NHST, researchers typically explicitly decide to minimize misses consistent with no more than 5 false alarm errors per 100. We accept some errors of one type (false alarms) in order to attenuate errors of the other type (misses), the specified percentage of false alarms is not always 5% but rather is as much as we can afford in that particular situation.

B. Paradigm Choice in TSD Framework

A similar trade-off between the two types of errors also faces us when we make decisions about what obtained functional relationships are plausible, what interpretations are acceptable for those obtained data, and even about what

paradigm we accept. We want our paradigm to consider all real issues no matter how obscure, without on the other hand, becoming bogged down trying to integrate information that only appears to be very important or real but which is actually illusory.

There is a trade-off between, on the one hand, the absence of serious research on phenomena (and/or their interpretation) which may really be correct but which are apparently inconsistent with the existing paradigm, and on the other hand the necessity of science to address itself to meaningful questions and to provide a credible theoretical framework for the phenomena on which it is focused. Consistency with the paradigm and paradigm revolution are the opposite poles of paradigmatic decisions just as reliability and detectability are opposite poles of statistical decisions.

This choice of paradigms is the most fundamental question we will face because it governs the types of questions we will ask and what we consider acceptable answers. Paradigmatic decisions like any decision can be structured from a decision analysis perspective. Unfortunately, paradigmatic controversies are rarely explicitly cast in terms of how many false alarms we are willing to risk in order to decrease our misses by whatever we can, even though the statistical analog of this choice of a correct paradigm is well thought through.

1. Example Paradigmatic Decision

Consider the question: "At what point is it worth serious effort to investigate extraterrestrial causation of ancient artifacts?" It is certainly a possibility, and it certainly provides a simple answer for some phenomena. In order to elaborate the various challenges facing a paradigm, the paradigmatic question of whether or not space travelers built the pyramids (i.e., an interpretation of the data generated by the undisputed data that pyramids exist) can be plugged into a decision matrix.

		REALITY	
		TRUTH was spacemen	**TRUTH was human**
CLAIM	**SAY was spacemen**	Correct Detection of new paradigm	False Alarm (say spacemen when not)
	SAY was human	Miss (say human when was spacemen)	Correct Rejection of erroneous paradigm

Figure 12.4 A standard decision analysis contingency table illustrating the outcomes when the decision is with respect to how the pyramids were built

Our interpretation could be wrong in two ways: 1) claiming that spacemen built the pyramids when humans built them, and 2) claiming that humans built the pyramids when spacemen really built them. Similarly, our paradigm could be

right in two ways: 1) claiming that spacemen built the pyramids when they did, and 2) claiming they did not, when they did not. Both claiming spacemen causation and claiming human causation has its advantages and its problems and each has some evidence that seems to support it and some evidence that seems to refute it. The bottom line is that there is a cost benefit ratio to each decision. (Note that there is no disagreement concerning the existence of the pyramids rather the disagreement is over how the pyramids came to be there.)

We must weigh all aspects of all factors in our decision. We must consider the weight of the evidence for each alternative as well as the cost and benefit of each possible outcome.

Please follow the subsequent logic by tracing through the decision matrix in the preceding figure. What we must simultaneously consider is the gain if we accept extraterrestrial causation and it is true (correct detection), with respect to the cost if it is false and we claim that it is true (false alarm); versus the gain if the extraterrestrial causation is false and we claim it is false (correct rejection) with respect to the loss if it is true and we claim that it is false (miss). Note that the two possible consequences for one decision (we claim the effect is true) are compared to the two possible consequences for the alternate decision (we claim the effect is false).

2. Deviation of Phenomenon and Paradigmatic Limits

The issues involved can best be illustrated with figures. The following figures represent the factors underlying decisions and therefore are topologically similar to those used in statistical decisions. Unfortunately, there is little data upon which to base the shape of the distributions, but having a concrete example requires a concrete graphic, so Gaussian distributions are used to illustrate paradigmatic relationships because Gaussian distributions are familiar. Keep in mind however, that the only essential detail of the figure is that the main function falls off with increasing distance from the central tendency while the alternative function rises with increasing distance.

The first figure below (Figure 12.5) is intended to illustrate that: 1) only findings and their associated interpretation within the range of the paradigm's tolerance are accepted as plausible findings and acceptable interpretations (correct rejection); 2) Some findings or interpretations may be inappropriately integrated within the existing paradigm (missed opportunity to advance to a better paradigm) (miss); 3) some facts could falsely be attributed to error or to an alternate paradigm when they are better integrated within the existing paradigm (false alarm); and 4) some findings may be so anomalous that we must change our paradigm in order to accommodate them and we would be correct in doing so (correct detection).

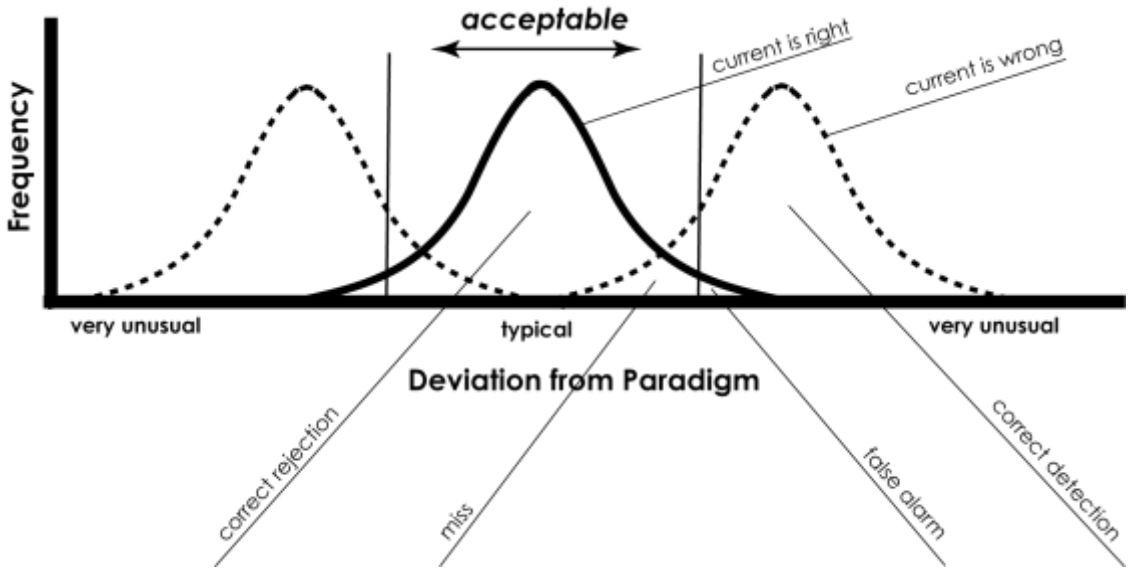

Figure 12.5 Standard format for depicting decision analysis in terms of areas under the distribution (see Figures 3.11 through 3.19). In this case the various components are labeled for decisions regarding correctly detecting when a shift to a new paradigm is required.

Note that we necessarily presume that the existing paradigm is correct; i.e., we are entirely sure that people did in fact build the pyramids just as we necessarily presume someone is innocent until proven guilty. Temporally switching to the familiar wind-versus-bear example (even though it is a strained example), we have total confidence that there are no bears when they have been extinct for 100 years. There are three aspects of this unswerving commitment to the paradigm's perspective: 1) all events are considered the result of the accepted paradigmatic laws (everything is wind); 2) there are no events which are the result of a different paradigm (there are no bears); and 3) the most deviant event possible is either the operation of the accepted paradigm in an unusual but paradigmatic situation (strong wind) or is an error.

This confidence in the paradigm is best illustrated by considering a magic trick. To a child, a new paradigm (magic causation) is required by the very unusual event of a coin disappearing. To the physicist, the event was by definition, an illusion and represented the operation of the accepted paradigm, just as well as any other observation. There can be no such thing as a disappearing coin or any other magic within our current physics paradigm. The burden of proof is on the anomalous event not on the paradigm.

Having stated all of that, we still must consider that both misses and false alarms could in principle happen. Note the criterion lines in Figure 12.5 and that there is a "current is correct" function beyond that criterional deviation and a "current is wrong" function before that criterional deviation (in the sense of proceeding from the center of the acceptable paradigm outward to larger deviations). Correct rejections are, of course, instances where the existing paradigm correctly explains phenomena and correct detections are instances where a new paradigm was correctly invoked to explain an event. False alarms are those aberrant findings and unacceptably different interpretations that are in

fact simple examples of the operation of the current paradigm. Misses are those findings which appeared to be well explained and integrated by the existing paradigm, but which are, in fact, instances of the operation of a different operating principle.

When a new operating principle or paradigm is accepted, then all current findings are re-explained with the new paradigm so that all previous findings are subsumed under the new explanatory system not just those that had been beyond the criterion plus what were previously considered misses. Secondly, recall that we don't actually have to believe that all phenomena are within the paradigm, we just have to simply act in every possible way as if we do totally believe it (if there is actually a meaningful difference between those two alternatives).

3. Deviation of Phenomenon and Paradigmatic Gain/Risk

The next figure illustrates the gain/risk principle underlying choices of paradigms. Note again that we have little data upon which to base the shape of the illustration but having a concrete example requires a concrete graphic. The actual shape of the deviation that the prototypical-paradigmatic statement and potential-for-gain functions take is unknown. Take the shapes as arbitrary.

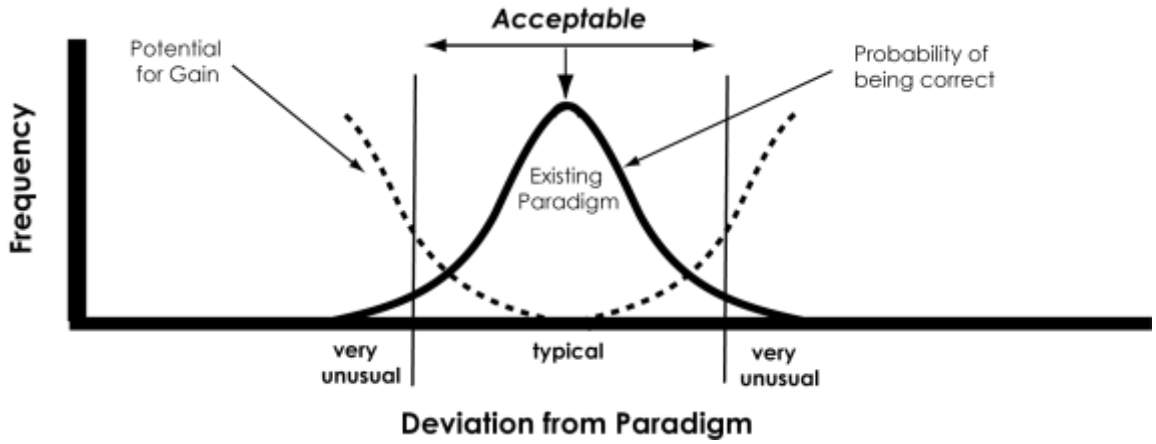

Figure 12.6 The standard format for depicting decision analysis. In this case, illustrating that as a finding and interpretation are increasingly discrepant from the existing paradigm, the potential for gain increases but the likelihood that the view is correct decreases.

The preceding figure (Figure 12.6) illustrates that as findings and their interpretation deviate from the normally accepted paradigm, the potential for gain by switching paradigms increases, if the findings and interpretations are correct. The potential for gain increases with the discrepancy of the finding from the paradigmatic norm because the greater the discrepancy from a normally accepted interpretation, the further off from truth the existing paradigm had been.

But it is also the case that the further off the findings are from the paradigmatic norm, the less likely the new interpretation is to be correct because of the breadth of support for the existing paradigm and the novelty and narrowness of support for the new interpretation. A choice of doing paradigmatic

research versus doing non-paradigmatic research can therefore be seen as somewhat like the choice between taking a single small step in a direction very likely to be toward your destination or taking a giant step in a direction which is virtually always wrong. The paradigm specifies a range of views that optimize the gain/risk decision. Historically, many small but correct steps gain more in the long run than a few giant steps that are likely to be wrong. This is one of the reasons that suggesting that a paradigm change is warranted is reserved for very extreme situations.

C. Paradigm Choice and Reduction in the Complexity of Explanation

The next four figures illustrate the factors underlying an actual choice of a paradigm. In order to best illustrate the factors, three-dimensional figures would be needed. Unfortunately, in the absence of 3-dimensional graphics, you must combine the next figure (Figure 12.7) which gives the front view (right to left) with the second figure (Figure 12.8) (which gives you the front to back) and then go back and similarly combine the next figure (Figure 12.7) (right to left) with the third figure (Figure 12.9) (which gives a more correct version of the front to back information). Ideally, the text would provide two, three-dimensional figures each with the same right to left face but with different front to back faces.

Absolute final wisdom could be considered as being at the minimum point of a function indicating complexity of conceptualization or explanation (the minimum in the curved function provided below). Final wisdom could be seen as the point that minimizes complexity of explanation for everything in the universe (noted with a star).

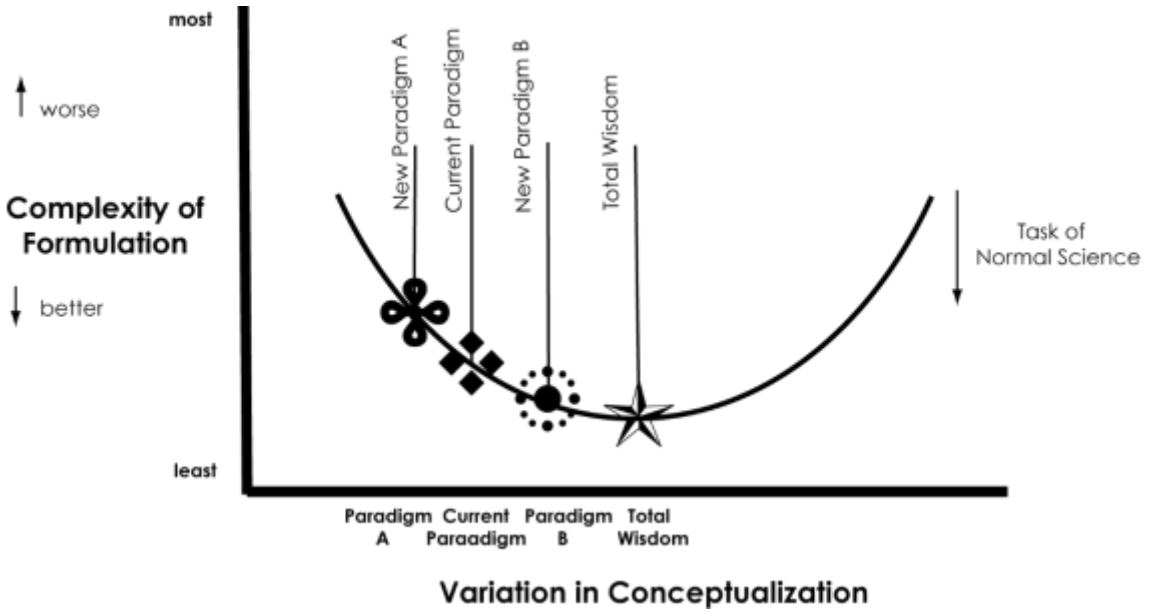

Figure 12.7 A depiction of the relationship between the complexity of formulation of various paradigms when they are at maximum development.

Our current existing paradigm (the point indicated with a ❖) is that perspective which minimizes complexity to the best of our knowledge. (Note that we act in every way as if we are already at total wisdom.)

All attempted shifts to some other paradigm could be seen as either decreasing the eventual best possible net complexity of explanation, or increasing the eventual best possible net complexity of explanation. Those paradigm changes that reduce best possible net complexity are seen as good; those changes increasing net complexity are seen as ill advised.

If all choices of a paradigm were as simple as the above Figure 12.7, then paradigmatic decisions would be easy. The next two figures illustrate the source of the difficulty in evaluating the appropriateness of various competing paradigms. The first (Figure 12.8) is overly simplistic, while the second (Figure 12.9) is more general.

1. If Equal Local Complexities of Explanation for All Phenomena

If different paradigms were better or worse at handing findings as illustrated in the above figure (12.7) and within each paradigm every conceivable finding was handled equally well, then net complexity and local complexity would be the same thing and the following figure would provide the side view of the preceding figure. (Imagine the above Figure 12.7 is 3-dimensional and extends down through many pages and you wish to look at it from the side. Alternatively, imagine the above figure (Figure 12.7) was looking at a car head on (front view) and now you wish to look at it from the side (side view). (If the below figure (Figure 12.8) were the side view, we would not need a three-dimensional figure to illustrate the differences in how various paradigms handle various specific local findings because for every single local finding, the relationships between the various paradigms would be identical.)

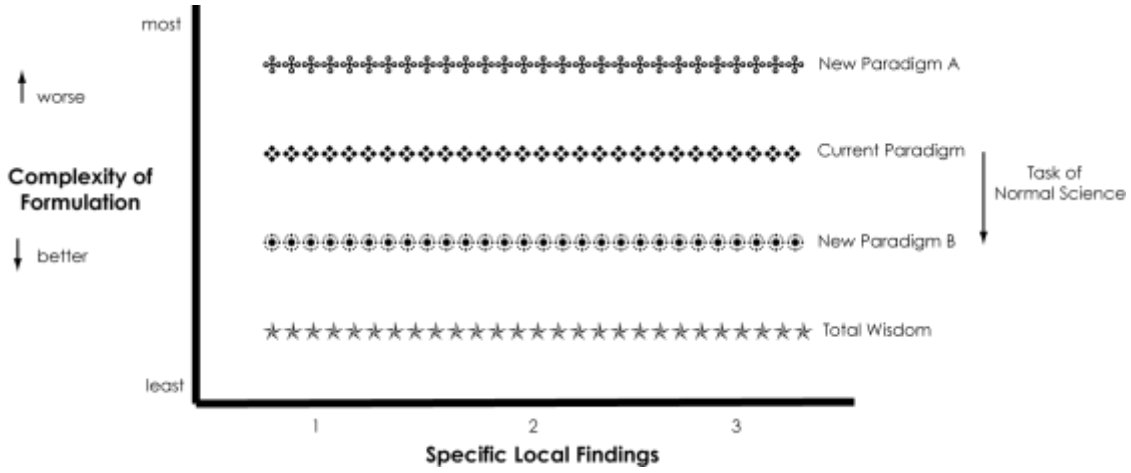

Figure 12.8 Side view Number 1 for complexity by paradigm (Figure 12.7). This frame illustrates the scenario where each specific paradigm handles every specific local findings equally well.

The above side-view figure shows that each paradigm handles each specific local finding exactly the same as every other local finding. Paradigm A handles everything worse than our current paradigm (i.e., in every case it has more complexity) and Paradigm B handles every specific finding better than our current paradigm (i.e., in every case it has less complexity).

2. If Differing Local Complexities in Explaining Various Phenomena

But, the above figure (Figure 12.8) does not represent how various paradigms actually handle various local findings. Each paradigm does not handle every single local finding equally well; as a result, net complexity is determined by how the paradigm handles many specific local phenomena in an overall sense. For example, burning down your house is a very simple and fast way to get rid of mice. That approach is extremely good at solving the mouse problem. However, you create a very large problem concerning where you are going to sleep at night.

A paradigm does not handle every possible phenomenon equally well. A good paradigm must be the best possible in its net result. The following figure more correctly illustrates the side-view variations in the ability of various paradigms to handle both local complexity and net complexity. Note that the presumption is that even though our paradigm does not handle every problem equally well, with more normal science the paradigm will handle every problem in the best possible way whatever that is.

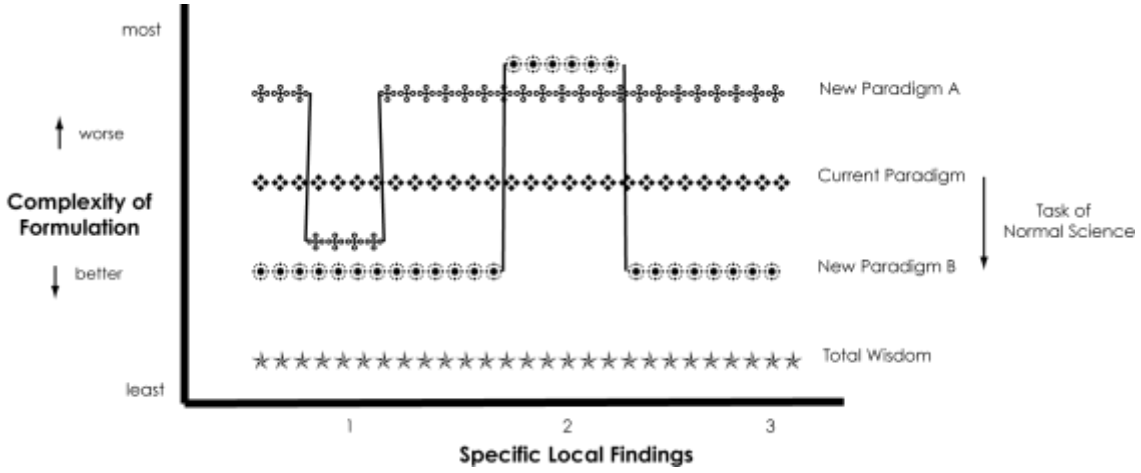

Figure 12.9 Side view Number 2 for complexity of formulation by paradigms (Figure 12.7). In this case the various paradigms handle different findings with different amounts of complexity. This demonstrates that the complexity of formulation for each paradigm is only a mean of various degrees of complexity.

The above figure (Figure 12.9) shows the more appropriate side view of the first figure (Figure 12.7) in terms of a set of three local findings. As can be seen in the above figure, the net or average complexity of paradigm A is greater than the existing paradigm (even though it handles finding 1 better than the current paradigm). The net complexity of paradigm B is less than the existing paradigm

(even though it is worse at handing finding 2 than the current paradigm). The assessment of the net complexity of each paradigm is the case even though for phenomenon I paradigm A is less complex than the existing paradigm. For phenomenon II paradigm B is worse than even paradigm A. Paradigm A may offer the illusion of simplicity when it claims that space men built the pyramids. The good part is that it solves in a very simple manner, the origin of the pyramids. The problem is that the other increases in complexity that that notion brings. Is there any evidence, at all, that space men built the pyramids other than our inability to figure out how the pyramids were built? How did spacemen get here? Why did they use wood and stone tools? Where did the spacemen come from? Are the artifacts on their home planet the result of other ancient astronauts, perhaps ancient Egyptians? How do we explain the artifacts on the first planet in the universe?

When it comes to deciding whether or not to shift to a new paradigm because it handles some problem better than the existing paradigm, the crux of the task is how to gain by reducing our net false alarms without unacceptable increases in our net miss rate or vice versa.

Historically, those people who have been most concerned with eliminating false alarms at the risk of accepting a few misses (stick with existing paradigm even when it seems like it should be abandoned) have been dramatically more productive at both arriving at the most consistently predictive models and in helping mankind. Wild flashy theories like wild goose chases have just not paid off. If we think through all of those factors that govern the trade-off, then we can better decide when to call for a paradigm change that we will not come to regret.

D. Decision Point or Tipping Point Optimization for Paradigm Revolution

The following figure (Figure 12.10) is an elaboration of the original front-view figure (Figure 12.7) with quantified values provided for various advances made by normal science (reduction of complexity by working within the paradigm). Paradigm A can be seen as proceeding from .90 complexity down to .30 complexity. Presume that the current paradigm has already reduced complexity down to .60 via normal science. Total wisdom can be seen to have a complexity of zero. Potential paradigm shifts (attempted reduction in complexity by changing paradigms) is indicated by the arrows emanating from the current paradigm at its current complexity of .60

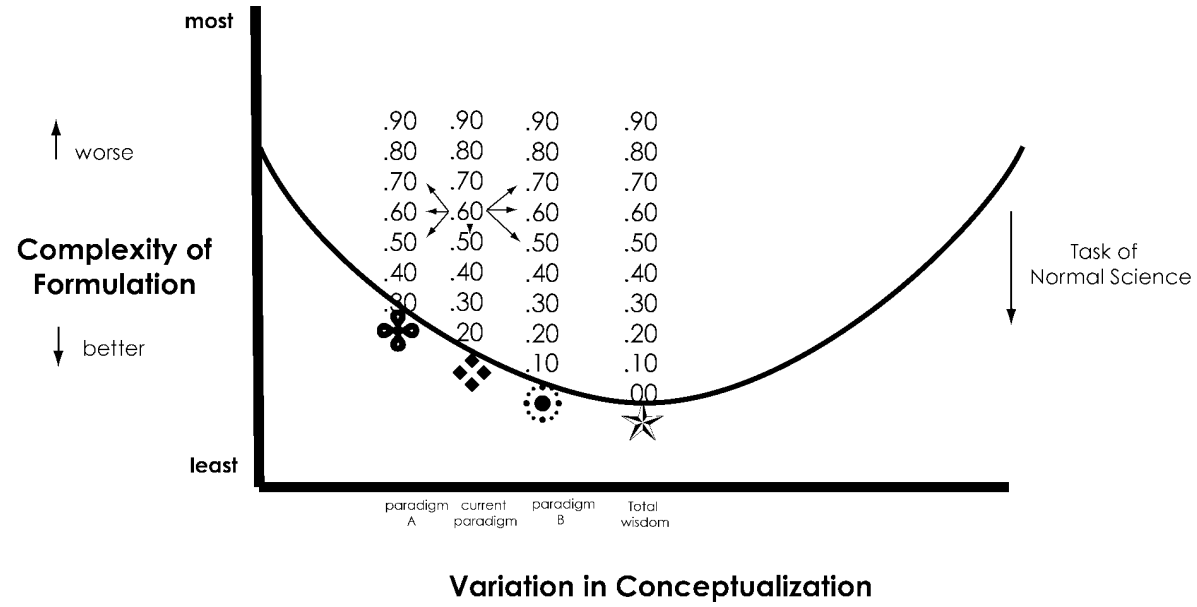

Figure 12.10 A re-presentation of the complexity of formulation by paradigm illustration of Figure 12.7 with stages in complexity given a numerical value to illustrate the changes in complexity when proceeding within a paradigm with normal science (the numbers decrease when going down a column), and the numbers can get better, stay the same, or get worse when changing paradigms. Note that the lowest value in paradigm A is 30 and the lowest value in total wisdom is 0.

Advancement in understanding nature within a particular paradigm (normal science) can be conceptualized as movement toward less net complexity of formulation by moving down the columns of numbers that represent degree of net "complexity within each paradigm." Normal science can be seen as moving the implementation of a paradigm to its best possible implementation (movement from 1.00 to the smallest number in a column down a vertical line of numbers which represents the best reduction of net complexity within the limits of that specific paradigm). At any point a researcher can: 1) conduct normal science and better account for phenomena within the paradigm (for example, in the existing paradigm movement from 0.60 toward 0.20) or the researcher can 2) move to another paradigm by changing paradigms in this case to Paradigm A or to Paradigm B.

(Please trace out every subsequent example on Figure 12.10.) For example, suppose that the current state of complexity was 0.60 in the existing paradigm. From "Existing Paradigm Position 0.60" a researcher could develop the following views: 1) Paradigm A Position .70 (an increase in complexity); 2) Paradigm A 0.60 (no change in complexity); 3) Paradigm A 0.50 (a decrease in complexity); 4) Existing Paradigm Position 0.50 (a decrease in complexity); 5) Paradigm B position 0.70 (an increase in complexity); 6) B 0.60 (no change in complexity); or finally 7) to B 0.50 (a decrease in complexity).

Researchers who advance the Existing Paradigm (i.e., E 0.60 to E 0.50) always advance knowledge by definition. Researchers who shift paradigms virtually never decrease net complexity (advance knowledge) in the long run. This is because there are vastly more dead-end paradigms (e.g., paradigm A) than more

productive ones (e.g., paradigm B).

Shifts to alternate paradigms are usually made because the researcher can see an illusory local reduction in complexity. Going back to the figure showing how local complexity may be handled differently by different paradigms. This would be changing from an existing paradigm to Paradigm A because the data at Point 1. is seemingly better explained by Paradigm A than by our existing paradigm. Unfortunately, the chances are high that there will be an increase in net complexity in the long run.

The problem with paradigm shifts is that science will advance in the short run by shifting to Paradigm A 0.50 from E 0.60 but Paradigm A at its best (0.30) will have more complexity than the Existing Paradigm at its best (0.20).

The problem of choosing to conduct normal science (E 0.60 to E 0.50) and when to be the leader of revolutionary science (E 0.60 to A or B 0.50) is more apparent than real. The articulation of a new paradigm (A or B) is extremely rare and universally rejected until the existing paradigm is at its maximum capacity (E 0.20) so that movement to a different paradigm is virtually assured to be in the right direction (E 0.20 to B 0.10) or even E 20 to B 20). Going from E 0.60 to A 0.50 appears to be a good move but it is a dead end. Movement to paradigm A will not occur when the existing paradigm is at its limit. E 0.20 to A 0.30 will be an obvious increase in complexity.

The reluctance of a scientific community to switch to a different paradigm is well illustrated by the fact that the Ptolemaic paradigm was maintained for quite a while after it exhibited glaring anomalies. Only after the Ptolemaic paradigm had exhausted all possible gains through normal science was the Copernican paradigm considered. Oddly enough, it had more complexity and accounted for fewer phenomena than the Ptolemaic solar system. It would be a change from existing 20 to B .30! It was considered only because the existing paradigm had been at a total dead end and the new view offered the possibility of eventually accounting for more complexity via normal science. (People were actually willing to stick with an existing paradigm until the alternatives all appeared to be a step backwards.) It was necessary to bottom out the paradigm before anyone was willing to even consider an alternate organizational scheme.

E. Strategies for Maximizing Paradigmatic Detectability

Given all these problems associated with paradigm change, we can systematically consider those factors that may increase our ability to know when it is and is not appropriate to abandon the existing paradigm. This will enable us to have a more appropriate conceptualization of the paradigmatic nature of science and increases the ability of our research to maximally inform us about nature.

Again, the following figures show Gaussian functions but the actual functions are unknown and could be anything and positioned anywhere.

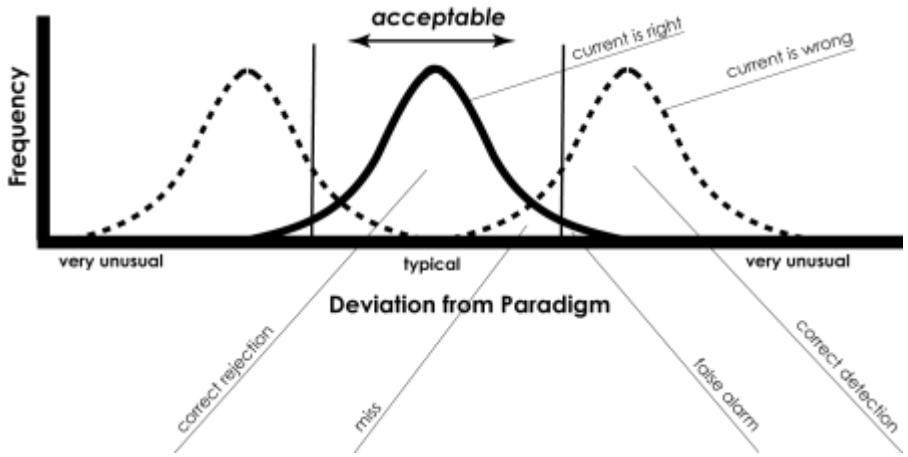

Figure 12.11 A re-presentation of Figure 12.5 for convenience. The standard format for depicting decision analysis in terms of areas under the distribution In this case, the various components are labeled for decisions regarding correctly detecting when a shift to a new paradigm is required.

1. Sloppy Use of the "Paradigm" or Eclectic Framework to Maximize Paradigmatic Detectability

Sometimes people assert that if the scientific paradigm were not so demanding about the reliability of its data, we could discover more. The hope is that by decreasing the demand for paradigmatic consistency, we may increase the likelihood of arriving at a better paradigm, but this is both true and false. It will make it possible to find a better paradigm (correctly detecting new paradigm) but it will also dramatically increase the likelihood of arriving at a wrong paradigm (false alarm).

In point of fact, it is more likely to arrive at error, because the number of ways to be wrong vastly outnumbers the number of ways to be right. Poorly thought through theories or sloppy research cannot be justified simply by claiming that they will decrease misses, because being less stringent in our emphasis of factors which maximize theoretical consistency will only make it possible to arrive at a better paradigm. The problem is that demanding that all facts and functional relationships be interpreted in a way that is consistent with the paradigm may decrease detectability but decreasing consistency does not necessarily increase detectability. It could just as well decrease detectability. As it turns out, sloppy thinking or sloppy research is actually less likely to discover a better paradigm than research with an extremely high criterion for consistency. The issue is subtle.

In order to make it easier to understand, a mundane example based on drawing playing cards from an honest deck will be used. Given that we hold a jack, in order to get a better card, we will have to switch to a new card. BUT: the fact is that the probability is that we will get a worse card. (There are more worse cards in the deck than there are better cards) unless we have some way to know that the card will in fact be better. This would be the case if the cards were marked and we knew the code.

This issue can be illustrated with the following figures. As can be seen, it is

essentially the same as the one used to illustrate any decision theory trade-offs.

Note: read the "1" side first followed by the "2" side in each row of the figure.

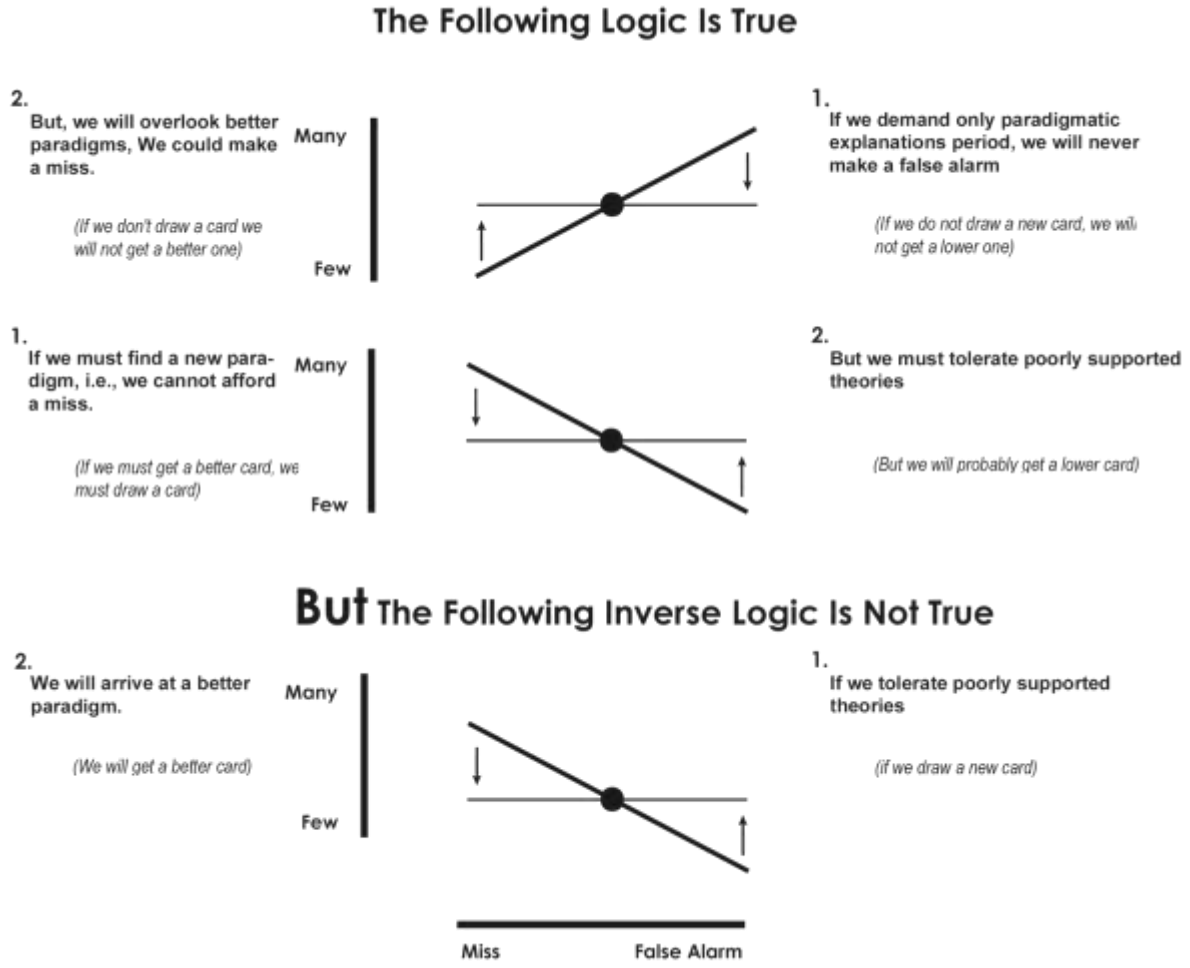

Figure 12.12 The competing goals of decreasing false alarms and misses first presented in Figure 3.15. In this case a step-by-step consideration of the logic of trying to increase the detectability of a paradigm. Read the "1." Legend first followed by the "2." legend at each level of the figure.

Variations in the criterion for acceptable hypotheses vary the frequency of accepting false paradigms and missing correct paradigms. More stringent criteria are the result of demanding more paradigmatic consistency. Less stringent criteria attempt to increase detectability by decreasing, 1)the demand for consistency, 2)the reliability and validity of the research, and 3)the rigor or the logic. It is the same dilemma as was presented when discussing the same issues in the statistics section.

The key, of course, is to try to discover what we can do to get the best of both worlds. The proverbial "sweet spot" the first step is to determine what factors

affect the proper execution of normal science and what factors affect the proper point of paradigm revolution and how they interrelate.

The following is a systematic elaboration of the various ways to increase paradigmatic detectability and uses the same figures as the previous statistical detectability section because the logic is identical and the rationales are identical.

The take home is: it would be nice to have more than a jack but the risk is too great to take a draw until the existing paradigm fails, is not getting better, and it absolutely requires change.

2. Conceptual Precursor: Graphical Representation of Paradigm Choice

Recall the explanation for the graphical representations used for analytical decisions. The same figures are used for displaying the same issues when discussing the choice of paradigms. While analytical decisions are easily translated into a single (or two) dimensions, decisions regarding paradigms are multi-dimensional. Try to abstract the discussion that was visualized and therefore based on only a distance to the right of the base distribution into some very complex multidimensional distance from some very complex multidimensional base. Secondly, keep in mind that Gaussian distributions positioned in a particular location are used because a concrete figure requires a concrete exemplar. Similarly, all figures portray effects to the right of the base distribution for simplicity.

3. Decrease Criterion Stringency to Increase Detectability of Paradigm

Making increasingly extreme demands that data and interpretations be reliable or consistent with the paradigm will increasingly exclude more phenomena and interpretations from consideration thereby increasing misses. Typically demands for consistency are deliberately limited to some criterion with the intention to exclude questionable phenomena or interpretations that are beyond that deliberately established criterion, while at the same time including as many phenomena as possible.

However at other times, there is a deliberate attempt to find phenomena rather than to assure that the finding is consistent with a large theoretical structure (i.e., decrease misses).

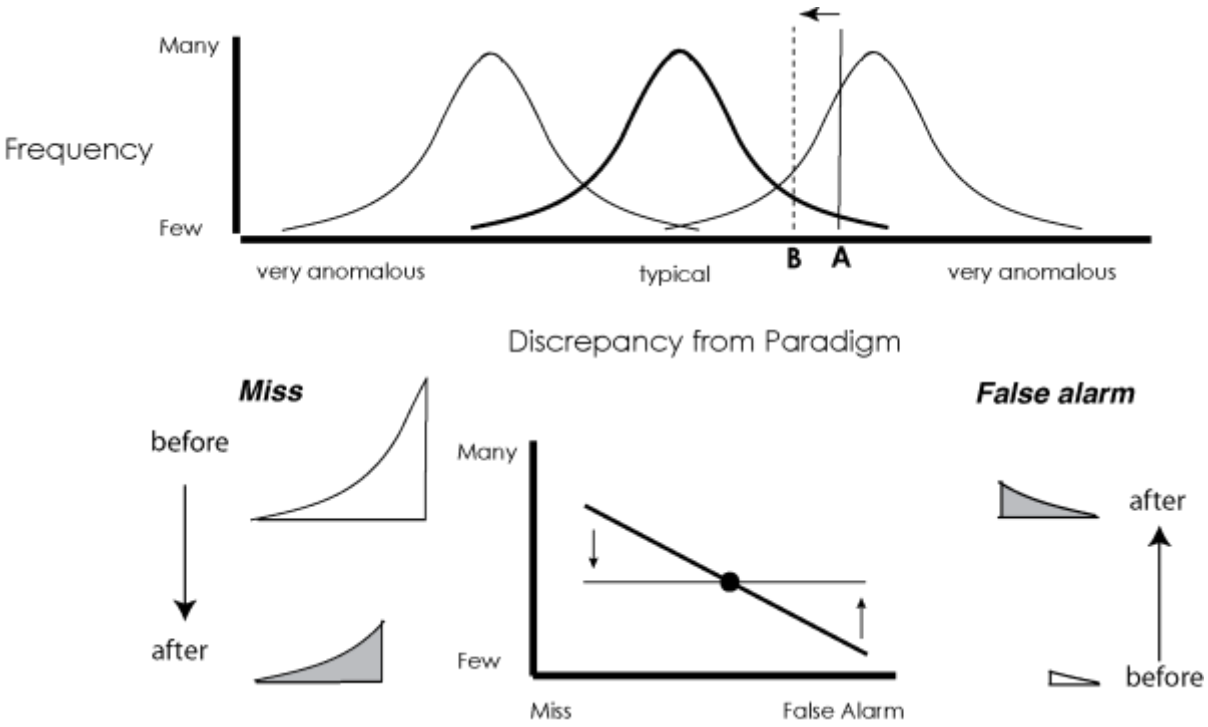

Figure 12.13 The standard format for depicting decision analysis (see Figures 3.11 to 3.21 and Figure 12.1). In this case the illustration is the effect of decreasing the criterion for paradigm change.

In that case, we could decrease the stringency of when to jump to a new paradigm. We could be less diligent in finding a paradigmatic explanation for phenomena that were resistant to normal explanation. This would allow us to accept some other paradigm that has less support and to abandon our existing paradigm with less provocation (because we couldn't make the paradigm explain our findings.) For example, if we cannot figure out how the Egyptians drew straight lines, we can propose that the devices to draw straight lines were brought by space ships.

The cost of this decrease in our criterion for abandoning the existing paradigm is an increase in theoretical false alarms. We will more often propose erroneous paradigms that waste a lot of researchers' time. But sooner or later, we may find a better paradigm. The down side of this simplistic approach is the fact that the likelihood of jumping to a productive paradigm is nearly zero. Returning to the card drawing metaphor, we will almost always draw a card worse than a jack.

Note that this method of increasing detectability is not based on an unprincipled paradigm but rather decreasing the criterion of switching from a principled one.

4. Increase Signal-to-Noise Ratio to Increase Detectability of Paradigm

a. Increase Compellingness of the New Paradigm to Increase Signal-to-Noise Ratio

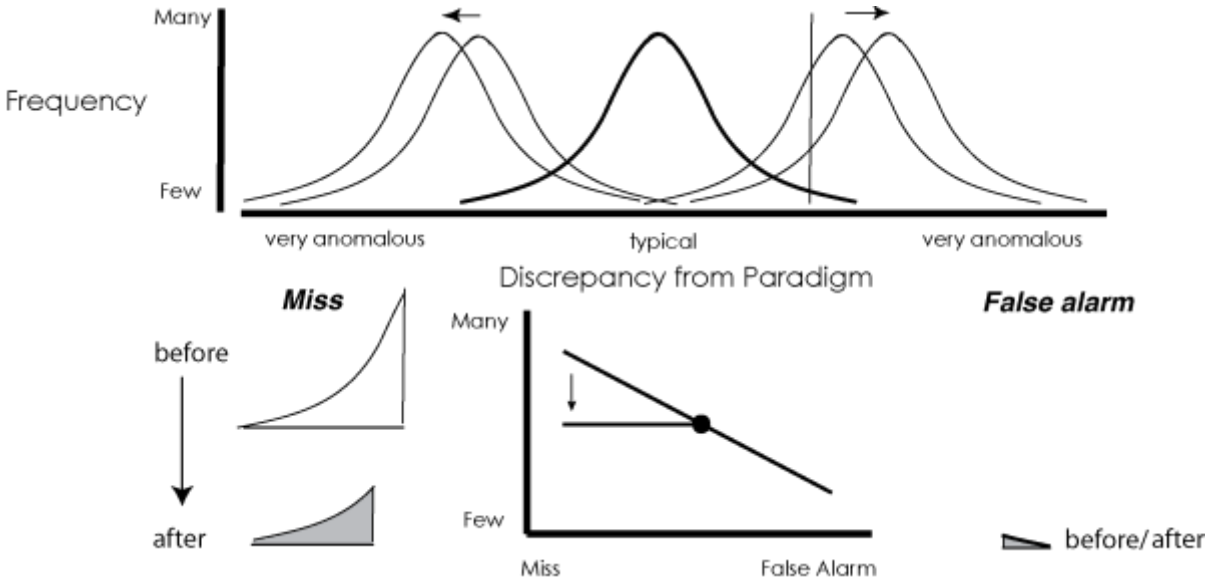

Figure 12.14 The standard format for depicting decision analysis (see Figures 3.11 to 3.21 and Figure 12.1). In this case depicting the effect of increasing the compellingness of the anomalous findings to facilitate the decision of when to change paradigms.

This is the cogent presentation of well-supported facts and interpretations that are clearly outside the ability of the current paradigm's explanatory power. This is making the new finding clearly different than the paradigm. This is increasing the magnitude of the signal.

The value of this type of research is that it decreases the likelihood that the proposed alternate paradigm is wrong. If we present enough solid evidence integrated into a coherent paradigm, we can make geologists of the 1940s believe plate tectonics (and psychologists of the 1950s to accept the value of behavior analysis). Prior to the well-documented evidence, the assertion that continents floated around on the surface of the planet was seen as preposterous.

In terms of the above figure, this type of research makes the discrepancy of the findings from the existing paradigm's ability to explain especially large thereby making the findings more compelling. The finding is moved out into a region clearly not covered by the existing paradigm. The obtained functional relationship "stands alone" well outside the explanatory power of the existing paradigm.

This approach is best when it also includes an alternate explanatory framework or paradigm which:

1. reduces complexity/increases scope
2. promises even further simplification with further normal science
3. is supported by experimentum cruces

Returning to the card drawing metaphor, this would be increasing the chance

of drawing a queen, king, or ace by coming to discover the code used by a previous card shark to mark the deck and thus pick a card that is higher than a jack rather than taking any card at random.

b. Demonstrate Failures in the Existing Paradigm to Increase Signal-to-Noise Ratio

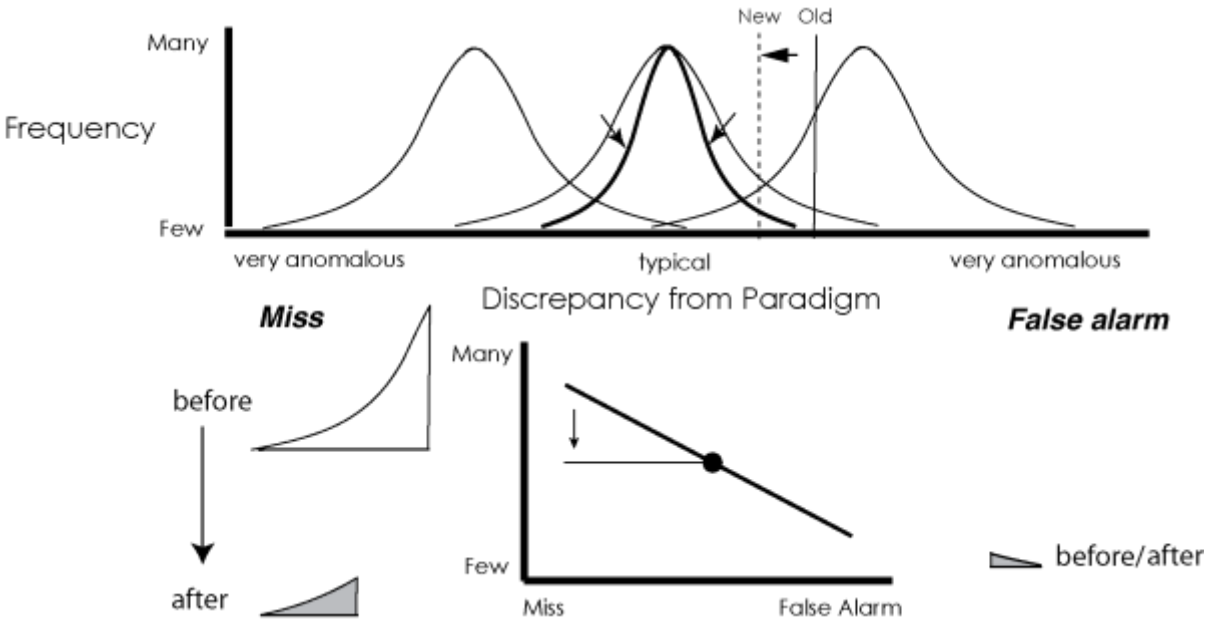

Figure 12.15 The standard format for depicting decision analysis (see Figures 3.11 to 3.21 and Figure 12.1). In this case, the depicting of the effect of decreasing the applicability of the current paradigm to facilitate the decision to change paradigms.

This is the narrowing of the range of applicability of the existing paradigm ("noise" distribution) with the cogent presentation of well-supported problems with the explanatory power of the existing paradigm which:

1. dramatically limit the range of explanations which the paradigm provides
2. show complexity in the existing paradigm
3. show that failures or complexity is likely to increase with further normal science

For example, narrowing the range of applicability and correctness of a putatively qualitative theory with a quantitative formalization. With clarification, many apparent explanations and consistencies are shown to be illusions. With a quantitative model, errors of prediction are more apparent and a better model is easier to identify. In Psychology, Hullian theory was shown to be inadequate by the research presented by Tolman and behavior analysts.

What this narrowing does is to decrease the number of phenomena that the

existing paradigm handles well by pointing out inconsistencies. This is reducing the magnitude of the "noise" distribution. Unfortunately, this is equivalent to increasing the heat under the "frying pan" in which someone sits. Without a better alternative to which to the person can jump, the result of the jump is as likely to be into the fire, as anything else.

Returning to the card drawing metaphor (which in this case is strained), this procedure reduces the rank of the card you have. It's rather like rereading the rule book and finding that a jack is a relatively low card (it is a knave and scoundrel) rather than being a high card.

CHAPTER 13

Optimization of Knowledge Gathering / Problem Solving (Research): Generality and Meaningfulness

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I. Generality Maximization

A. Definition of generality or "external validity"
B. Factors pertaining to the generality of a functional relationship
   1. conceptual precursor: terms applicable to the issue of generality
   2. the strategies or assumptions underlying the chosen basis for generality
      a. maximized similarity
         i. cautionary note: the concept of similarity
      b. maximized paradigmatic validity (understanding)
   3. property across which generalization is made
   4. the use to which generalizations are put
      a. explanation
      b. prediction
   5. origin of the data enabling the generalization
      a. formal principled determination of generality
      b. generality based on successful use of an intuitive extension into a unique situation
      c. generality based on the correction of a failure to correctly generalize a functional relationship
         i. cautionary note: causation
   6. broadening the database in order to increase generality
C. Paradigmatic goals and procedures
   1. subject variables in the generality of sample results to the target population
      a. generality via understanding: proxy or model subjects
      b. generality via similarity: representative subject
   2. apparatus or setting variables in the generality of sample results to the target population
      a. maximize generality by maximizing understanding
      b. maximize generality by similarity: "real world" settings
   3. procedural variables in the generality of sample results to the target population

II. Meaningfulness Maximization

A. Conceptual review: covariance and accountable variance as meaningfulness
B. Maximization of statistical meaningfulness by increasing percent of variance accounted for
    1. increase magnitude of effect (given a noise level)
        a. methodologically
        b. mathematically
    2. increase magnitude of noise (given an effect size)
        a. methodologically
        b. mathematically
C. Maximization of paradigmatic meaningfulness
    1. partitioning the ability of a paradigm to predict nature
        a. maximize the ability of the paradigm to predict nature
            i. very broadest most fundamental aspects
            ii. middle level traditional aspects
            iii. shallow or least established aspects
        b. maximize ability of the scientist to use the paradigm
            i. understand the paradigm's assumptions
            ii. understand how the paradigm works
            iii. understand the paradigm's knowledge base

CHAPTER 13

Optimization of Knowledge Gathering / Problem Solving (Research): Generality and Meaningfulness

This chapter elaborates the last two of the four attributes that must be optimized in research: generality and meaningfulness.

I. Generality Maximization

Chapter 11 had developed the realization that information that is undependable is not a fact. To say something is true or a fact is to say that it can be made to recur or be replicated by reinstating the pertinent causal conditions. We know that it is a fact that the rate of key pecking increases when it is followed by food because the effect occurs every time we do it.

Chapter 12 had developed the realization that it is also essential that we discover functional relationships that are subtler than a smack in the face. We must optimize the detectability of our research and even our paradigm.

The first portion of the present chapter develops the issue of generality.

A. Definition of Generality or "External Validity"

To say something is generalizable is to say that the functional relationship is common in, or applies to, different situations. If different subjects, apparatuses, or procedures have functionally the same relationship, then the original functional relationship is said to generalize to those subjects, situations, and procedures. The test of reliability is the ability to be directly replicated or repeated under exactly the same conditions. The test of generality is the ability of a functional relationship to be systematically replicated or repeated in different situations. As is true for everything in science, generality, in the last analysis, is empirically determined. If the functional relationship reliably predicts in a new situation, then it is said to generalize.

There are both similarities and differences between the terms “stimulus generalization” and “generality of a functional relationship.” Stimulus generalization is the description of the fact that an organism behaves in a similar way to similar stimuli. Discrimination is the inverse and refers to the fact that the more different the stimuli, the more different the behavior. The generality of a

functional relationship refers to the degree to which a functional relationship obtained in one situation is able to predict what will happen in different situations. The more similar the situations with respect to the controlling relationship, the more similar the effect. The more different the situations are with respect to the controlling relationship, the more likely the relationship will be different.

The difference between stimulus generalization and generality of a functional relationship is that stimulus generalization is the relative similarity in the probability of instances of a known behavior as its controlling stimulus changes along some simple well understood continuum such as wavelength. The task of identifying instances of stimulus generalization are therefore easy. In the case of generality of a functional relationship, neither the stimuli nor the behaviors in the source and the target are necessarily the same, it is the functional relationship between those elements that remains constant. The identification and proof of generality is therefore more difficult.

For instance, given a pigeon pecking to a green key, stimulus generalization would refer to the continuation of pecking as the hue of the key changed. As the hue becomes less similar, the behavior persists albeit is less similar. The generality of the functional relationship that key pecking increases when followed by food would refer to the fact that jumping increased after being followed with water, and singing increased after being followed with cheers. The functional relationship that generalized is the fact that the rate of a behavior increases when it is followed by a positive outcome.

With respect to knowledge gathering, we want our functional relationships or knowledge to have generality in addition to reliability and detectability. Understanding the generality of a functional relationship enables the prediction of functional relationships in novel situations and provides for the explanation of them by way of establishing their commonality with a variety of situations.

The present treatment of generality refers to the commonality of a particular functional relationship across a variety of subjects, apparatuses, or procedures. A somewhat different treatment of generality is a special case and is focused on the applicability of a research finding back to some larger specified population

B. Factors Pertaining to the Generality of a Functional Relationship

1. Conceptual Precursor: Terms Applicable to the Issue of Generality

The set of all applicable individuals when taken together are called a population, whereas a subset of the population is considered a sample. An organism, situation, or procedure that is used to generate information is a model. When information is applied to a different situation we speak of that new situation as the target. For example, key pecking could be measured in pigeons in operant chambers and a functional relational relationship such as “response allocation matches reinforcement allocation” (a "model") could be taken as an indicator that that relationship also exists in the population, of all living animals in all situations involving choice between reinforcement rates (the "target"). Research could be carried out in several different situations to determine the validity of the

characterization. If supported the functional relationship would have generality.

2. The Strategies or Assumptions Underlying the Chosen Basis for Generality

In sum, knowledge can be generalized from a model to a target on the basis of simple naive notions of similarity, or on the basis of understanding what's going on. This has led to two research strategies: 1) research emphasizing simple similarity to the target to maximize generality, and 2) analytic research emphasizing the understanding of as many of the mechanisms of action involved in the original population or context as possible to maximize generality. In either case the characterization must be supported for it to be considered general.

“Similarity” research is often done in the “real” world with real people or at least primates. Real world subjects or settings are maximally similar along some dimension assumed to be important in an effort to establish generality of the obtained functional relationships. If the goal is to solve an applied issue quickly and simply then this approach is typically taken. Unfortunately, the simplicity can introduce many confounds which seriously undercut the actually obtained generality, as well as limiting the information it produces.

"Analytic" research on the other hand is structured to maximize the ability to understand the true causal factors. “Understanding” research is often done in the laboratory with the most apt synthetic situations and the most apt non-human subjects with the highest degree of experimental control possible to maximize generality. It is the approach taken when simply understanding the phenomenon itself is the goal. Unfortunately, synthetic subjects and settings could fail to produce generalizable information due to misunderstood or unaccounted for differences between the model and target.

a. Maximized Similarity

If a functional relationship is obtained and is then applied to itself, it of course applies; it is a simple description. If the original situation changes very slightly between the time the relationship is identified and then applied to itself, the information will probably still correctly describe or predict. However, it can be seen that the less similar the original model and target situation are along the dimensions which enable the generality the less likely that the finding will apply to the dissimilar target.

We may be able to increase the likelihood that information gained in one situation is applicable to another situation by making the two situations as similar as possible, hoping that the elements that are different are not important, and hoping that the factors that are the same are important. This is better than nothing but is not entirely satisfactory.

If the task is simply to develop knowledge applicable to a narrow range of target situations such as for simple practical knowledge, then naive notions of similarity will often adequately serve as a basis for predicting generality. For example, if research were done on children then it would be expected to apply to

children. This is the rationale underlying vocational training programs, such as Psy.D. and Nursing degrees. Simple practical knowledge is enough in some situations. It is important to realize, however, that the predictions work only when the target is coincidentally very similar along relevant dimensions to the training situation. If the practitioner is expected to predict in a variety of situations, errors of prediction will occur, and those errors could have important consequences. The ability to predict in a wide variety of situations and circumstances is, of course, what separates professionals from technicians. It is the well-accepted difference between nurses and physicians. It is rather like training someone to only say dolphin as opposed to training someone to actually see the dolphin in a SIRDS. Vocational training or practical experience need not prepare people to generalize into different situations while professional education must.

First, depending on naïve views of similarity may not work. The similarity must be similar with respect to the essential characteristic across which the generality is expected to occur. For example, humans are similar to humans, and fish are different from humans, however voting patterns of humans earning less than $10,000 per year do not predict voting patterns of humans earning over $1,000,000 per year; whereas the effects on a fish of being dropped onto the surface of the sun predicts very well what will happen to humans dropped onto the sun. It should be clear that we might have to generalize to targets when we don't really understand how they are similar or different with respect to the procedure at hand.

Secondly, a dependence on similarity to maximize generality represents a rather passive, timid and superstitious approach to science. If we deliberately minimize the difference between the model and target when doing research, then we minimize the opportunity to learn why things work the way they do by eliminating the knowledge gain provided by the rigorous determination of the factors governing the generality of findings. In the extreme case of minimizing differences, we could maximize similarity by using each subject and procedure as both the model and the target of prediction. Obviously, that would be nothing less than the abandonment of science. We would have to start from scratch with the next subject or the next procedure.

i. Cautionary Note: The Concept of Similarity

It is clear that the issue of generality is related to the definition of the word "similar." If the model and target are similar with respect to the controlling variables of interest, then the functional relationship will generalize. If the functional relationship generalizes then the procedures are by definition considered similar. It is important to avoid falling into the tautology fallacy when discussing similarity and generality.

b. Maximized Paradigmatic Validity (Understanding)

Paradigmatic validity refers to whether situations are actually related to each other the way the paradigm suggests that they are. Note that this is always

assumed to be true.

At the global level, whether a functional relationship obtained in one situation can be generalized to some target situation by way of the paradigm depends on 1.) whether the paradigm validly specifies the actual relationship between variables 2.) the breadth of its database and on 3.) the researcher's understanding of the actual causes of the behavior in the original situation and the correct understanding of whether those same factors are analogously in effect in the target situation.

At the particular level, it is important to realize that two crucial elements are needed to predict whether an effect will generalize to a different situation: 1) why it occurred in the original situation and, 2) how the new situation relates to the original situation with respect to the relevant causal factors. In an entirely alien reality you would have great difficulty predicting what would happen in new situations even if you knew why things happened in the original situation. This is because you would have a very poor idea of the circumstances in which to expect those analogous controlling factors again. Rather like Alice in Wonderland, you cannot make accurate predictions unless you know the rules by which the situations are connected.

A previously noted example of true controlling variables being other than what they appear to be at first glance would be the Abbott and Costello comedy routine "Who's on First." The joke pivots on the realization that who (etc.) is a person's name and their assigned position is to play first base (etc.). As a second example, laughter following telling a joke functions as a reinforcer while moans function as a punisher. However, laughter following telling a pun functions as a punisher while moans function as a reinforcer. Reinforcement and punishment are operative in both situations; but what will function as what must be understood in the context at hand in order to understand if the effect in the target will mimic the effect obtained in the model.

3. Property Across Which Generalization is Made

Generality can be across any combination of the subjects, the apparatuses, or the procedures. In each case the generality can be based on the similarity of the situations, or based on the formal understanding the of the pertinent variables.

4. The Use to Which Generalizations are Put

a. Explanation

An obtained functional relationship in one situation which is common across situations could be used to help understand new results. There is almost no end to a complete explanation for even a simple phenomenon, however, an approximation or partial explanation is to be had with the experimental demonstration that a causal process is necessary and sufficient and is a common process in a variety of well documented other situations. When searching for an explanation for an effect similar findings in other research can be sought.

b. Prediction

An obtained functional relationship in one situation could be used to predict an effect is some other situation. The prediction could be based on simple similarity or could be formally predicted by way of rules specified by some other research. In either event a procedure could be developed and implemented based on a warranted expectation of generality.

5. Origin of the Data Enabling the Generalization

a. Formal Principled Determination of Generality

A totally formal, principled system for generalizing an effect is not currently available. Our knowledge base is not up to the task. It would require rules for translating an extremely broad set of observed relationships into novel dimensions, as well as some way to quantify the spread of effect within those dimensions. Generality is typically identified and proven after the fact, rather than formally predicted for every possible situation by the paradigm.

b. Generality Based on Successful use of an Intuitive Extension into a Unique Situation

Successful generality in this case comes after the fact, the intuitively arrived at "prediction" was empirically supported. Subsequently, following experimental support, that basis for similarity can be used as a basis for generalizing in the future.

c. Generality Based on the Correction of a Failure to Correctly Generalize a Functional Relationship

Generality in this case would be based on making predictions to situations only hoped to be similar. The failure to generalize correctly may lead to an insight into a functional relationship which does lead to successful well supported generalizations. For example, data from a simultaneous discrimination had been used to predict what would happen in a serial discrimination. The prediction was that only a single peck would occur in the final stimulus of a clocked FI schedule because only the final stimulus was thought to be paired with the reinforcer, all other stimuli were thought to be explicitly unpaired. The prediction was wrong. Rather, all stimuli in the second half of an interval controlled responding. This led to a better understanding of the appropriate meaning of what "paired with food" had attempted to characterize. The appropriate characterization of what stimuli control responding in both a simultaneous as well as a serial discrimination should have been "stimuli correlated with the reinforcer will control responding, those that aren't won't."

i. Cautionary Note: Causation

In the clocked FI example it would seem that it would have been a simple matter of simply noting that the stimuli in the last half of the procedure controlled responding in the original target research, therefore that must be the cause of the obtained data. That approach is fraught with potential errors, and is unacceptable. Additional research was required to substantiate the better definition of "paired with food". It is essential to keep in mind that simply seeing a relationship in the data does not prove that it is correctly characterized, important, or causal

6. Broadening the Database in Order to Increase Generality

Research on the operant as a function of schedules of reinforcement is well advanced, behavior other than operants and situations other than the few moments before reinforcement are not as well understood but could effect generality. They warrant additional research effort.

C. Paradigmatic Goals and Procedures

Recall that:

Behavior analysis is concerned with understanding the moment-to-moment changes in an individual organism's semi-permanent adaptation to covariance in the environment that emerges and is lost across the seconds-to-days time scale ("i.e. learning")

This paradigmatic goal results in a very fundamental difference between the procedures appropriate to, as well as, how the results of those procedures are interpreted in behavior analysis and traditional psychology. For example, In traditional psychology, the task is to find the effect of a ideal instance of a procedure on an ideal individual i.e. "the effect of the variable on a subject". As a result, individual differences are seen as errors in measurement to be canceled out by using the average across individuals. In behavior analysis, on the other hand, the task is to understand how short time scale adaptation occurs in the particular individual at hand, as a result of the moment to moment changes in the contingencies of reinforcement for that particular individual. Individual differences are the essential data. In point of fact, individual differences are used to demonstrate generality. In behavior analysis three subjects are used in an experiment not to find the average effect, but rather to demonstrate generality across subjects.

1. Subject Variables in the Generality of Sample Results to the Target Population

The subjects used must in some way give us knowledge we can use with respect to other subjects.

a. Generality Via Understanding: Proxy or Model Subjects

Proxy subjects are model subjects used in lieu of subjects "similar to" the target subjects. They are often used in order to maximize the degree of control over confounds and to therefore be maximally revealing of the phenomenon of interest. For example, pigeon subjects are used because their history and motivation can be controlled. It is also easy to eliminate distractions during experimental sessions with inexpensive isolation chambers. Additionally a pigeon can emit an easily recorded behavior virtually continuously for hours thus revealing very detailed aspects of the moment-to-moment effects of reinforcement. The effects of food pellets as a consequence to a pigeon has been proven to generalizes to the effects of a wide variety of reinforcers for humans and other species. An additional important considerations for using proxy subjects include their convenience. A pigeon is simply easier to deal with than a person or a whale.

b. Generality Via Similarity: Representative Subjects

Generality of research in this case is based on making the model subjects as similar to the target subjects as possible. The conceptually simplest option is to use the same population in the model and the target to assure subject generality. That is not an option if the target is all humans on earth. The only alternative is to measure a subset or sample of the entire population and then to infer that the results obtained on the model generalizes back to the target.

The success of the generalization depends on the target being similar to the model. That is not always the case. For example, the verbal report of what American college freshmen enrolled in an introductory psychology course claim they would like to eat is unlikely to generalize to what rural Chinese farmers would say.

In some cases, The sampling techniques that selects the subjects must be forced to assure representative subjects.

2. Apparatus or Setting Variables in the Generality of Sample Results to the Target Population

Assuring that the subjects provide data that generalizes to the target is not sufficient to assure the broadest generality of obtained functional relationships. Apparatus or setting variables can strongly affect the generality or the applicability of the functional relationships derived in one situation and applied to another but are often overlooked The selection trade-offs are the same as those

involved in selecting subjects: maximum similarity versus maximum understanding.

a. Maximize Generality by Maximizing Understanding

Proxy situations minimize error through the deliberate choice or design of the apparatus or setting and adjusting those parameters to optimize generality. Obviously, the generality of the research depends on the correct interpretation of how the apparatus or setting variables in the original and target situation are related.

b. Maximize Generality by Similarity: "Real World" Settings

As previously pointed out, "real world" situations maximize generality through similarity, but also typically maximize error through lack of control. For example, shouting "fire fire!" to a student in an experimental cubical volunteering for a psychology experiment is unlikely to result in any useful data. They will be expecting some kind of trick. An experimental setting in a university building and in an isolated run down building a night are totally dissimilar with respect to the believability of fire. Secondly, real world settings are often not optimized to provide the data needed to understand the phenomenon or how to generalize the functional relationship to other settings.

3. Procedural Variables in the Generality of Sample Results to the Target Population

Establishing the applicability of research results across procedural variations involves the same issues as does establishing the applicability across subjects and apparatuses: i.e., generality based on similarity versus generality based on understanding.

The behavior analytic approach to generality is almost exclusively by way of understanding. This is especially true when it comes to procedure variables. The behavior analytic approach to procedural generality is by way of implementing a multiple schedule and directly comparing the two procedures within subjects and within sessions. A single-subject design, is focused on explicitly determining how the variables of interest control the same or different behavior and why. This is an proactive approach to generality. The applicability is explicitly determined. Generality across intervening parameter values of the explicitly tested procedures can be estimated with great confidence. The results of the research specify when each functional relationship should be expected and how to adjust the procedure to obtain or eliminate them.

II. Meaningfulness Maximization

It is not enough to simply maximize the likelihood that someone else will get your results if they exactly repeat your procedures; or that you made every effort to find small effects; or that they will get your results if the methodology varies in some way. Your findings must also be meaningful. You must account for as much of the variability in your research findings as possible. If you are an emergency room medic it is more meaningful to discover arterial bleeding than ingrown toe nails even though both require medical treatment. The identification of the importance of the consequence of operant behavior on the rate of that behavior class, is a more meaningful discovery than the discovery of the functional relationship that animals salivate when given lemon juice.

The concept of meaningfulness maximization takes two major forms in psychological research: 1) it is important that variations in your independent or predictor variable account for a large proportion of the variation in your dependent or predicted variable (i.e., statistical meaningfulness) and, 2) you must maximize your ability to make your paradigm make sense of all the booming, crashing, apparent randomness in nature by maximizing your understanding of the existing paradigm and/or making a better paradigm (i.e., paradigmatic meaningfulness).

Maximal reliability, detectability, and generality are necessary for maximal meaningfulness, other things being equal.

A. Conceptual Review: Covariance and Accountable Variance as Meaningfulness

Covariance is the amount of uncertainty that has been reduced by the knowledge of something else, or more formally the variance accounted for. Meaningfulness is the degree to which the predictor variable allows better predictions of the dependent measure than nothing. If the predictor allows no better predictions than guessing the mean of the y scores, then no variance is accounted for. If the predictor provides for perfect predictions of the dependent measure, then the predictor accounts for 100% of the dependent measure variance.

If you are not now fully comfortable with the meaning and implications of covariance and variance accounted for, take a moment to review that material in Chapter 5 at this time.

B. Maximization of Statistical Meaningfulness by Increasing Percent of Variance Accounted For

The research must account for the highest proportion of the variance in the obtained data as possible.

1. Increase Magnitude of Effect (Given a Noise Level)

This is increasing the signal-to-noise ratio. This approach includes all the

previously discussed methods for increasing the magnitude of an effect. The two strategic approaches are briefly reviewed below.

a. Methodologically

This is a choice of subjects, apparatus, and procedures that result in a very large effect of the treatment. For example, the procedure could specify a large dose of drugs or other independent variables in order to produce a strong effect.

b. Mathematically

Large sampling windows capture more information, just as larger telescopes or larger satellite dishes capture more signal. While hearing a single thump may not mean much, a series of thumps in the pattern of footfalls getting louder are a strong signal that something walking this way comes.

2. Increase Magnitude of Noise (Given an Effect Size)

This is maintaining the same (or better) signal-to-noise ratio in the presence of higher levels of noise. Increasing the magnitude of noise in the baseline in order to increase the percent of variance accounted for sounds counterintuitive. It is based on the premise "given equal levels of reliability." If you buy a doorbell that can be heard even when you're having a wild party, then your confidence that you will hear the doorbell under normal conditions is high.

In order for an effect to be equally reliable with a very noisy baseline (typical a small sample size), the effect will have to be much larger so that it will be equally obvious in spite of the noise in the baseline or control group. Showing that the effect is robust in the face of noise increases our belief in the meaningfulness of the effect. Showing that an effect is significant to the 0.05 level only when 250,000 subjects are used suggests that the effect size is quite small. Reinforcement is reliable even with only a few subjects and even across species, behaviors, and reinforcers.

a. Methodologically

Start with only a few animals. Use a variety of subjects, apparatus and procedures. If the effect is reliable with only a few subjects or across a variety of procedures, then by definition it is a relatively strong effect capable of swamping the noise.

b. Mathematically

Take a smaller sample or use a statistical test of low power such as simple visual inspection. If the effect is clear enough to convince your theoretical opponents with only a short measuring period or with a low power test, then it is a very strong effect.

C. Maximization of Paradigmatic Meaningfulness

A paradigm must make sense out of the largest proportion of variance in the natural world as is possible. If a child misbehaves or a pigeon pecks a key, the paradigm must be able to make sense of both events. In point of fact, the behavior analytic paradigm can make sense of behaviors that divergent by noting that they both are the result of the subject's reinforcement history.

1. Partitioning the Ability of a Paradigm to Predict Nature

The error in a paradigm's ability to predict nature can be partitioned into that attributable to the error an adherent makes in applying the paradigm to obtained data, and the error attributable to the inability of the paradigm itself to account for the finding (both of these discrepancies are typically assumed to be zero in the practical conduct of science).

a. Maximize the Ability of the Paradigm to Predict Nature

The issue here is the degree to which the paradigm is in fact able to perfectly predict all the variance in nature. Obtained data is seen from a particular paradigmatic perspective and in that sense is filtered or approved by the paradigm, but on the other hand, the paradigm is maintained only so long as it provides the most productive framework within which to view data. Ultimately, the paradigm must answer to the reality of a productive interaction with nature.

i. Very Broadest Most Fundamental Aspects

The most basic demands of the scientific paradigm such as requiring consensual validation or empirical events have changed little in the last several centuries and are unlikely to change much in the future. These aspects have pretty much gotten to be the final word.

ii. Middle Level Traditional Aspects

These aspects of a paradigm are somewhat recent developments in the bigger scheme of things but have come to be pretty basic to the paradigm over the last several decades. Given the breadth and depth of their support, they are unlikely to change much in the future. Examples of these types of elements would be the role of microorganisms in infection in the medical paradigm and the role of reinforcement in the field of psychology.

iii. Shallow or Least Established Aspects

These aspects of a paradigm are important elements of the current paradigm and provide the frame of reference for the practice of psychology but are not as stable as more fundamental elements. For example, the central role of matching and molar or molecular views in behavioral research and theorizing could easily change. It goes without saying that the very shallowest levels of a paradigm or

those relevant to only a few labs change (or are updated) with every publication.

b. Maximize Ability of the Scientist to Use the Paradigm

The issue here is the degree to which an adherent is able to use all of the explanatory power of the paradigm. The better understood the existing paradigm, the better that knowledge base can solve problems and understand the obtained functional relationships.

For example, it is pretty obvious that the more case precedents a lawyer knows, the more likely that lawyer will win, and the better the vocabulary and the broader the life experiences, the better the poet so it is with every science.

It is for this reason that reading pays off in science more than any other activity the researcher could do. The point of doing empirical research is to clarify questions. The better the quality of the question, the more efficient the research. Simply running animals and analyzing data for the sake of "doing research" and collecting numbers is virtually pointless.

i. Understand the Paradigm's Assumptions

There are foundation assumptions underlying every paradigm. You cannot understand or use the paradigm without them. These issues are the purpose of this text and this course. You cannot be successful at explaining a phenomenon if you don't understand what the scientific community believes is an acceptable explanation. For example, when trying to understand why the pigeon pecked the key, an answer such as "and then the pigeon realized that it needed to peck the key in order to get the food" would be seen as a self-serving tautology and would prove the speaker a nonscientist (in addition to being stupid). For example, if you were trying to discover how to enable someone to become a "better" person (often labeled counseling, psychotherapy, or psychiatry), then you will have the largest impact on that person if you see the task: 1) from a scientific perspective (the objective measures of empiricism, multiple converging evidence, etc.); 2) the correct level of molarity (organismic adaptation or psychological rather than cellular adaptation or biological); 3) from the correct time scale (short time scale adaptation or learning as opposed to long time scale or evolution); and 4) as determining what consequences are maintaining what behaviors and how you can adjust the contingencies to result in the desired behavior.

ii. Understand How the Paradigm Works

Paradigms provide the explanatory context and machinery with which events in nature can be understood by its practitioners. The behavior analysis paradigm argues that following a behavior with a particular consequence can increase the rate of that behavior, and that the deliberate manipulation of that contingency can change the behavior of the organism. Additionally, it argues that there can be no meaning to "the person" other than the functional relationships relating the person's behavior to events in the natural world. It follows therefore that to create

a better person, the task is to reinforce "better" behaviors and to extinguish "worse" behaviors much as you would tell someone to draw cards and save the high ones and discard the low ones. The view would be that chatting with a person and trying to have them understand their early childhood experiences with their mother or establishing insight into their problem can be productive only to the extent that it simultaneously reinforces good behaviors and extinguishes or punishes worse behaviors.

iii. Understand the Paradigm's Knowledge Base

You cannot waste your time rediscovering what is already understood and you cannot waste your time simply doing research and collecting information that doesn't advance our understanding of the paradigm (because the functional relationship was already discovered or is irrelevant to the paradigm's database). A paradigm's knowledge base is like a partially completed jigsaw puzzle. Each new functional relationship revealed by research fits within the existing framework and contributes to completing the picture. In order to add to the completion of the puzzle, you must know what has been completed already (knowledge base) and what holes exist and what the holes look like (problems to answer). Otherwise, you have no idea whether the loose pieces you see around you (your research questions and answers) add to completing the puzzle, or are an irrelevancy, or had already been solved. It was because Fleming knew the puzzle so well that he understood where the penicillin effect on a Petri dish fit within the knowledge base.

A second important aspect of the process of science is that it entails the simplification of all the findings in the database through the identification of underlying commonalities or process not simply the accretion of more facts. Only by knowing everything that is out there, can their commonalities be seen.

Chapter 14
The Contribution of Knowledge to the Field of Psychology

I. Why Perform Experiments or Do Research

A. Because research produces knowledge
B. Because research is fun
   1. indulge curiosity
   2. challenge
   3. social reinforcers

II. Sources of Problems to Solve

A. Research problem from expert
B. Research problem from folklore
C. Research problem from insight
D. Research problem from informal discussion
E. Research problem from knowledge of techniques and apparatus
F. Research problem from reading the literature
   1. sources of research literature
   2. how to find additional sources of problems to solve
   3. how to read research articles
G. Research problem from a paradoxical incident or conflicting results
H. Research problem deduced from paradigms or theories

III. Activities Which Solve Problems and Produce Better Knowledge

A. What if ... / indulgence of curiosity
B. Verification, replication, and systematic replication
   1. direct replication
   2. systematic replication
C. Improving measurement
D. Unconfounding
E. Specialization
F. Generalization
G. Technological advancement
H. Recombination
I. Establishing the existence of a new phenomenon
J. Testing prediction from theory
K. Construction of functional context

L. Integration of finding into an existing coherent framework

IV. The Process of Discovery

A. Research strategy
   1. deductive or premeditated design research approach
      a. comparison of results to an a priori prediction
         i. a priori prediction based on intuition
         ii. a priori prediction based on theory
         iii. a priori prediction based on model (quantitative theory)
      b. post hoc realization of functional relationship
   2. inductive or dynamic research approach
      a. discovery via post hoc organization of data
         i. comparison of results to known functions
         ii. description of functional relationship
      b. discovery via construction of functional context

B. Research tactics
   1. be committed
   2. be well read
   3. balance novel and mainstream
   4. focus on productive relationships
      a. reliable robust relationship
      b. apt and optimal elements
      c. large potential for gain
   5. maximize your chances to discover
      a. simplify to essential case
      b. sort in terms of similarities and differences
      c. search for regularities
      d. optimize visualization
      e. be open-minded
      f. recognize errors as breakthroughs
      g. drop everything if necessary
   6. be alert
   7. be ingenious
   8. be relentlessly focused
   9. be diligent, meticulous, compulsively accurate, and scrupulously honest

CHAPTER 14

The Contribution of Knowledge to the Field of Psychology

An important aspect of understanding behavior analysis, or any other science for that matter, is understanding why people contribute knowledge (do research), how people do research, and where the questions come from.

A discipline advances because people like you have an idea that is better than the existing body of knowledge. Adding understanding to the field of psychology is fun, exciting, and gratifying. The process of generating knowledge can be seen as asking why or having a perplexity, and then doing something to answer it objectively rather than subjectively which is to say you can easily prove it to people who don't already agree.

One of the most exciting things about science is its infinite supply of really important questions. There are as many research questions left as there are songs or novels left - and for the same reason. It all depends on your ingenuity. There are more than enough great discoveries for everybody. On top of that, all of humanity may be better off because you chose to answer your question. The next time you confront a problem and have an idea that may solve it, **do it**!

I. Why Perform Experiments or Do Research

A. Because Research Produces Knowledge

Knowledge is behavior under the control of covariance in nature, or in everyday terminology, knowledge is understanding covariance. It allows you to help others and help yourself by knowing what events in nature reliably covary with other events in nature. The functional relationships you discover will enable future researchers and practitioners to behave appropriately in the situations you illuminate.

B. Because Research is Fun

It is so much fun, many researchers talk about doing research as a socially beneficial addiction. A quip says it all, "don't discova if you wanna recova." There are three aspects of doing research that makes it fun.

1. Indulge Curiosity

It's intrinsically fun to explore or discover. It's what drove Columbus west. It's what compels children to take apart toys to see how they work. It's what compels scientists to take apart behavior to see how it works.

2. Challenge

Rising to a challenge is what makes us have pride in ourselves and it's what makes us grow. Crossword puzzles are fun because they are hard not because they are easy and have obvious solutions.

3. Social Reinforcers

When we discover something, we gain knowledge that other people do not have. We then have the opportunity to give them something that they want. This ability to give people what they want or need is the motivation, which underlies the joy of giving gifts at Christmas.

II. Sources of Problems to Solve

Problems can be conceptualized at a number of levels. At one level we are all searching for the answer to the question "why do organisms behave the way they do?" Questions can evolve toward more specificity such as: from why do humans behave the way they do, to how does reinforcement affect behavior, to how does reinforcement affect studying, to how does reinforcement affect studying for tests in university males? Alternatively, beginners may start with relatively specific research problems focused on only the face value of the question, but eventually develop a broad research question with great generality. For example, what started as: "how can I help my roommate study more?" evolves into "what controls studying in people?" to "what controls the behavior of organisms?" At the beginning, the roommate's behavior is at issue for itself. Later the person and the behavior are seen as arbitrary instances of a much more important and challenging question. Career-long research problems tend to emerge following several years of specific research topics, and those research programs require many specific research studies to solve.

This section details some of the sources for an initial, relatively specific, research problem. It is intended to help you come up with research that is manageable, enjoyable, and productive.

A very serious impediment facing new researchers is well illustrated by trying to use a foreign language dictionary to learn what some foreign word means. Until you know enough of the foreign language, you cannot find out what the words mean because the dictionary is written in that foreign language. Experienced

researchers would be like someone who speaks French using a “French” dictionary to look up a French word. Similarly, until you know enough of a “foreign” paradigm, you don't know what unresolved questions remain, or when the paradigm is wrong. A person's first exposure to a research project is often as an assignment or a class project for that reason.

In addition to not knowing what unresolved problems remain, beginners often do not see the more fundamental broader issue underlying a specific behavior change. For most people, it’s difficult to go from “a pigeon pecking a key faster when the key is blue,” to “a stimulus associated with a higher reinforcement rate controls an increase in the response rate.” It is a challenge to see a specific behavior as an instance of a general class of relationships if you don’t already know what the dimension of the commonality is. This was alluded to in the chapter on generality when discussing the commonality of key pecks, singing, and studying.

A. Research Problem from Expert

The simplest source of a problem to solve is to have it given to you; as a class assignment, as a directed research project, or as a task while you are an apprentice in someone's lab. You are told what problem to research and how to do it. This is the ideal way to assure that your first research topic is a good question and leads to a useful answer, that will reinforce all the work you put into it.

Example: Students in Experimental Psychology were assigned the task of finding out if social attention made their roommate study more. On alternate weeks, they were told to express interest in their roommate's course material each day as compared to weeks when they refrained from talking about academic topics as an independent variable. They were to measure the amount of time their roommate studied each day as a dependent variable.

B. Research Problem from Folklore

Common beliefs, common sense, or proverbs could be right but on the other hand, they could also be wrong and actually hurt people. It is possible that some unverified beliefs have the roots of a better idea and therefore would be a worthy research topic. The task is to verify that they are true before considering them as a source of knowledge.

However, it is critical to realize that the task of research, if it is to remain maximally productive, is not to simply validate or invalidate common sense but rather to come to understand nature, or to solve problems by characterizing the process and placing it within a principled paradigmatic context. There are more bad ideas out there than there is time to refute.

Example: It's commonly believed that studying within the two hours preceding a test will decrease test scores because it confuses well-rehearsed knowledge. To research this belief subjects were told to study immediately before taking a test on a random half of their tests while on the other half they were to do something else immediately before the test. This research was intended to determine

whether or not studying immediately before a test decreased the points earned on the test.

C. Research Problem from Insight

Sometimes people research an issue simply because it occurred to them and it seemed important (which may be true). The systematic development of the idea is lacking. This is "intuitive" or good guess research. It is risky because it may actually be a pointless idea. It is fun because you get to do what interests you at the moment.

Another instantiation of this rationale for research would be simply making a good guess that a new problem is nothing more than a well-understood functional relationship in disguise.

Example: While feeling especially competent after explaining course material to three friends you realize that a person orally and interactively presenting material may help that person's performance on a test. You conduct a study in which the subjects orally present material before the test on a random half of the occasions. The research was based on your insightful realization that oral presentation may increase the test performance of the presenter.

D. Research Problem from Informal Discussion

This is a research problem that some discussion group feels is interesting. Discussion among friends can often spark our interest in a problem or provide us with the reinforcers for pursuing a question.

Example: After telling a group of friends about your success with researching oral presentations on test taking, the group talks about it for a while, and becomes interested in the possibility of the presenter becoming confused, as well as doing better as the result of the specific nature of the feedback from the listeners. The discussion group provides you with the idea and the excitement to do research on how students can affect the accuracy of a presenter's understanding.

E. Research Problem from Knowledge of Techniques and Apparatus

This is the selection of a research topic based on your special knowledge outside the field. A technique or apparatus with which you are familiar can offer the potential for a major advance in the field of psychology. Sometimes we realize that we can apply a new technique or apparatus to an area to which it has not yet been applied. Because it is a person's unique skills or knowledge that has led to success, solving the problem can be especially gratifying for that person.

Example: You may know about microelectronics and be good at detailed work. You find out that many researchers are anxious to discover the migration patterns of butterflies so you become the first researcher to mount a pico-sized integrated circuit GPS transmitter on butterflies and thereby trace the behavior of individual free-ranging butterflies.

F. Research Problem from Reading the Literature

These are research problems that capture your interest while reading. While reading, you will often wonder "why", or will disagree, or will realize that you have a better idea than the original author.

Example: While you were reading about jet lag and its effects on sleep the first night at the destination, you realize that the author failed to control for light cycle. You try stretching either the light period or stretching the dark period to make up the phase shift. You implement this by changing how the cabin illumination period is adjusted on various trans-Atlantic flights, and then monitor the passengers' sleep for the next three days.

1. Sources of Research Literature

Initially, it may be hard to know where to start reading in your quest for knowledge. Consider backing up a bit and starting at a very general level and then working your way down to the more specific. In this way, you will have a better understanding of the context for your idea and what important variables may be.

The web is an easy to access, broadly based, searchable source of knowledge. However, it has both strengths and weaknesses. The web provides easy access but keep in mind that some information is authoritative while some is written by 7th grade computer geeks who are better at creating professional-looking web pages than having sophisticated well thought out opinions; or by erudite sounding writers who have more enthusiasm for their opinions than evidence. Wikipedia provides a reasonably authoritative source but its weakness is that anyone can amend the information. It is well known that a few highly motivated editors can introduce an extreme bias to a Wikipedia entry. As a result, its authoritativeness, especially in controversial areas, is questionable. Additionally, its treatment is relatively shallow and may do little to help you understand the complexity that inevitably surrounds complex information. Finally, web-based abstract search engines such as PsycINFO, PubMed, and Psychological Abstracts allow you to easily access peer-reviewed and therefore the most authoritative information in the form of journal articles. But, you have to have a idea of what you want, and be far enough along to be able to use the advanced information.

A library-based strategy is to first quickly skim through several Introductory Psychology textbooks to understand your research question and its connection to the whole field at the broadest possible level. Then look through several middle level textbooks that cover the particular area in which you are interested; Conditioning and Learning texts, for example. It is easy to understand the structure of your specific area by reading the Table of Contents of these middle level textbooks; you can then read the specific section relevant to your precise research topic. Note the original research that led to the general paradigm and conclusions. Pay particular attention to the theoretical significance of various types of results and to the functional relationship depicted in the figures (figures of processes are worth more than a thousand words). In order to broaden your knowledge base in the specific area of your research question, note the authors,

titles, and dates of the journals and books that are referred to in those the middle level texts. Then go to the web, access, and read them.

To review your search algorithm:

Web search
Introductory texts
Middle-level or area texts
Annual Review / Review articles / Special topic text / Symposium reports
Journal articles

2. How to Find Additional Sources of Problems to Solve

Web search
PsycINFO
PubMed Central
Psychological Abstracts
Current Contents
To find the research that led up to an article of interest, refer to the reference page of that article
To find the research that grew out of an article of interest, refer to The Science Citation Index.
Knowledgeable people

3. How to Read Research Articles

Actively participate while you are reading. At first it will keep you from falling asleep, later it will keep you from thinking about other things, and eventually it will make the reading a lot of fun. Keep in mind however, that just as it takes time to learn to play a musical instrument or master any skill, it will take time to learn to stay focused on and remember and integrate the myriad of essential fine details which you must attend to while reading journal articles. Just as the joy of playing a piece of music comes from the sum of many small skills developed across a relatively long time, similarly, the joy of reading a journal article is from the integration of many small skills developed over a relatively long time of reading articles.

Underline important ideas, write questions and answers in the margins, and keep an idea log.
Draw a diagram of the procedure.
Consider how the research bears on your interests.
Look for what's important.
What was the research problem and why must it be answered?
What subjects were used and why?
What apparatus or setting was used and why?
What general procedure was used and why?
Was the procedure applicable and the best available?

What was the independent variable, how was it measured, and what was it inferred to be doing (its interpretation) (e.g., did shock produce fear or something else)?

What were potential confounds (alternate explanations) and how were they controlled?

What was the dependent variable, how was it measured, and what was it inferred to be the result of, or what did it represent (its interpretation)? (e.g., was faster responding because of better learning or because of greater motivation?)

What were the empirical results, what were they interpreted to mean, and to what extent is it likely they would happen again if the experiment were replicated (the reliability)?

How sensitive was the dependent measure? If the effect was real but very small, would the research have been able to prove it (the detectability)?

To what extent will the findings apply to other subjects, situations, and procedures (the generality)?

How much of the variability obtained could be accounted for? (the statistical meaningfulness)

What was gained by the research ("so what")? How has the paradigm been extended by this finding? (the paradigmatic meaningfulness)

Developing your skill of productively reading is the single most important skill between you and career success. Recall that only a moment's reflection is necessary to realize that the TV character "House" could only be as successful as he was if he were more widely read than anyone else, and he could maintain that advantage only if he read journals in every spare minute. Where else could all his miraculous up-to-the-minute knowledge come from? The winner in the race to be most knowledgeable goes to the person who is the most widely and most thoroughly read and is the most current in the literature. The only way to get that way is to be constantly reading (even after graduating!), and to be reading more than your competition. The day you stop constantly reading journal articles is the day you start slipping behind the leader of the pack. It is not your confidence that you know everything, but rather the reality of how much you actually know.

G. Research Problem from a Paradoxical Incident or Conflicting Results

If the world is perfectly understood, then there can be no surprises. Contrariwise, if something surprises you, then your theoretical framework is inadequate and needs development. If two seemingly similar procedures produce different results, then something is wrong with our understanding of the processes engendered by the procedures. The two procedures are not actually similar in the important respect of how they affect the dependent variable. Given that a misunderstanding has occurred, something is not correctly understood and knowledge gain is available. What is it that is making the results different?

H. Research Problem Deduced from Paradigms or Theories

Researchers who propose theoretical accounts for phenomena cannot think through every possible ramification. As you come to understand a theory, potential errors or extensions become apparent because of your idiosyncratic experience. This type of research tests the implications of theories to confirm or reject them. This is classic deductive normal science.

An extremely good example of a counterintuitive but true prediction deduced from a theory is the previously presented Rescorla and Wagner's overexpectation research. If response strength approaches asymptotic response strength on each reinforced trial as asserted by Rescorla and Wagner, then reinforcing a compound stimulus of two asymptotically conditioned stimuli should result in a response decrement to each stimulus. This loss should be apparent on subsequent tests when those stimuli are presented alone.

The challenge becomes, which paradigmatic framework provides the best explanation for overexpectation; while at the same time best explains the broadest range of data, and provides the best framework for understanding future research findings.

III. Activities Which Solve Problems and Produce Better Knowledge

Once you have a general understanding of why you would want to do research and a topic you want to understand, you can usually go forward. Generally, a research task is abstract and could be solved by any of a number of activities. But sometimes it's hard to decide exactly what activities to engage in, or how to conceptualize the kinds of things you might do in that specific research area. Often it is said that we do research in order to discover new information or discover the cause of something or even simply to answer why. Unfortunately, these goals don't give beginners much of a handle on what activities to actually engage in.

If you have difficulty knowing what to do to start doing research, your research question may be too global for a beginning. Start with a more specific question. At its most specific, a research question is simply a specific research activity. A general approach to help you get started, therefore, may be, to not start with "how can I solve the problems of the world?" Rather, start with how can I help my roommate study more, or even how can I get my roommate to sit at a desk? Then think of the more general issue of exactly what does studying mean, how would you know it if it were happening, and what factors influence studying? Then eventually, why does behavior work the way it does? The answer to this final, most general statement of the specific question is pretty close to "how can I solve the problems of the world?"

A. What if ... / Indulgence of Curiosity

This activity is perfectly acceptable research. Simply do what seems like an interesting manipulation. Your background led you to wonder what would happen if you did it, it's likely that other people may have the same question. In fact, many important scientific discoveries were made because the researcher did exactly that: "I wonder what would happen if I do ...." The risk in this type of activity is that your manipulation may have already been studied or no one else may be interested in your question, or it may, in fact, be a bad idea.

Example: Building on the studying roommate example, you might want to know what would happen if your roommate were exposed to several people interested in the same course material.

B. Verification, Replication, and Systematic Replication

Some findings have only been demonstrated once. The original study could have been flawed. It is important that our knowledge base be on better grounds than a single demonstration. This type of research (i.e., verification) is one of the factors that enable science to be self-correcting.

1. Direct Replication

Example: Do an experiment over. Do everything exactly the same as the original.

2. Systematic Replication

Change the subject, apparatus, or procedure in order to obtain a slightly different perspective or slightly extend the research. In this case, you maintain the same process thought to be the causal factor (i.e., reinforcement), but you freely change whatever is thought to be an "irrelevant" specific factor (e.g., the specific operant behavior or the specific reinforcer). For example, if food got a pigeon to peck the key (arbitrary behavior), then you should be able to get your roommate to study with a food reinforcer (or social praise). Suppose you regulate when you both go out to eat and you always wait for some study behavior to be occurring before saying, "let's eat"!

C. Improving Measurement

Many pioneering research studies did not use what have become the best measures for the independent and dependent variable. Better research measures the behavior more directly rather than indirectly, and measures it more accurately. Additional improvement can be obtained by moving up from a nominal, ordinal, or interval, to a ratio scale.

Example: You refine the "interest" measure of the people talking to your roommate into those that simply show interest, those that ask for a fact, and those that ask for some integration of information. You then compare the effectiveness of each.

D. Unconfounding

Occasionally research is published with an unobserved confound which you may notice. The study can be redone without the confound.

Example: You read an article that manipulated a variable intended to increase studying (it failed). You realize that it was conducted during Saint Patrick's Day in Chicago, a town known by locals at least, for its partying on Saint Patrick's Day. You redo the experiment and run it during a normal week.

E. Specialization

General functional relationships may or may not apply to specific situations. You could measure what is proposed to be a general effect in a particular group.

Example: The effectiveness of social attention on studying behavior was examined in students from lower socioeconomic status families.

F. Generalization

Functional relationships obtained in a specific situation may or may not generalize to other situations or populations. You could measure behavior in other groups or other situations.

Example: The effectiveness of social attention on reading instruction manuals, road signs, and novels, rather than only academic behavior at a university.

G. Technological Advancement

A technological advance in one discipline may have an enormous impact on the production of knowledge in another discipline. New tools may reveal the answer to longstanding questions. If you have a particular research problem already chosen and you can bring new technology to bear on it - do it.

Example: Visitors at a zoo were monitored while near instruction signs using a TV camera with a telescopic lens. The effectiveness of other people asking questions on increasing reading was assessed.

H. Recombination

Sometimes the information we need is the synthesis of two or more previous functional relationships. The combination of two different research designs can provide a simple and elegant demonstration of a complex functional relationship.

Example: A 3x3 factorial design was used to manipulate educational level (4^{th} grade, 11^{th} grade, and university junior) and magnitude of social attention for studying (show interest, ask for fact, and ask for integration) on the amount of studying that ensued.

I. Establishing the Existence of a New Phenomenon

You may be interested in demonstrating some new functional relationship. In

this case, you would change your procedures around until you have a clear demonstration.

Example: You believe that the effectiveness of social attention is determined by specific experiences in life before the age of two. You find groups that react differently to social attention and examine their infancy and the data seem to support your hypothesis. You then randomly sort a new group of infants into two groups. You give one group your best guess of the critical experiences, the other does not get those critical experiences, and then you follow up by measuring the susceptibility to social attention of the two groups over the next thirty years.

J. Testing Prediction from Theory

The validity of a theory is assessed by generating a prediction based on the theory, and then testing that prediction to determine if the theory is supported. This is classical deductive research.

Example: Your theory predicts that the early determinant of susceptibility to social attention is effective because it affects the person's lifelong verbal skills. You compare subsequent California Grade School reading tests (grade school), SAT verbal (high school), and GRE verbal scores (university) of the two groups known to differ with respect to those critical early experiences and which have different susceptibility to social attention.

K. Construction of Functional Context

This type of research is required when an unexpected behavioral relationship is uncovered. This happens when existing theoretical formulations do not handle the result and, therefore, the experiences that increase and decrease the effect must be determined.

Example: You find that once someone begins to obtain reinforcers from one person regularly, other people do not function as reinforcers as well as they had. You then research various procedures until you track down the experiences that make the effect more extreme and which lessen or remove the effect. You also try to find other instances of a similar effect.

L. Integration of Finding into an Existing Coherent Framework

The identification of the experiences that cause a psychological phenomenon can be the goal of research. You may know of a particular functional relationship and be interested in discovering exactly why it works the way it does. This is classical inductive research. Note that underlying cause does not imply that you should be looking inside your subject. Rather, it means you should find the necessary and sufficient historical experiences to produce the behavior.

Example: Continuing the above research, you develop a model that specifies the ontogenic processes of which the particular effect is an example, and the types of experiences that potentiate or retard the effect

IV. The Process of Discovery

A. Research Strategy

Research can be "top down" or "bottom up." You can have a general view of how things work and want to expand or test that paradigm(top down). Alternatively, you may see a behavior and wonder why it works the way it does(bottom up). Research can be classified in terms of these strategic approaches. As a result, there are two major classes of systematic research. Each class generates knowledge by using a different logical approach, or by "coming at it from a different direction."

1. Deductive or Premeditated Design Research Approach

This first class of research begins from some knowledge base, attempts to extend that knowledge base by making a prediction, and then verifies that extension by comparing obtained empirical results to the prediction.

Alternatively, you may think a theoretical explanatory system within your context or your own lab (local context) has a flaw because you think some behaviors are the result of some other process. In this case, discovery is made by specifically designing research to provide some result that is inconsistent with the predictions of the existing theory while being consistent with the new theory.

The actual experimental procedures and exact results of these two goals have no intrinsic interest whatsoever, other than to support one set of principles while falsifying some other set.

a. Comparison of Results to an *A Priori* Prediction

In this subset of deductive research the study is specifically designed with the intent to compare some aspect of the results with what was predicted to happen. For example, as was given in a prior example, common sense would lead one to think that if you condition responding to two different stimuli and then reinforce the combination of the two stimuli; you would increase or at least maintain response strength. By carrying out the math in the Rescorla/ Wagner model it was predicted that combining two asymptotically conditioned stimuli and continuing the conditioning trials would reduce response strength to each stimulus. When the procedures were carried out with actual subjects the predictions of the Rescorla/Wagner model were verified. This is the prototypical "hypothesis testing scientific method" presented in textbooks. It is important that you clearly understand the theory and clearly think through exactly what is predicted by the theory before doing this type of research. The value of this type of research is entirely dependent on the correct understanding of the existing theory and the quality of the design proving a favorable or unfavorable result. There can be no alternative interpretation of the obtained results.

The first issue in theory testing research is that the existing theory can have no way of explaining the obtained behavior. Secondly and ideally, there can be

only one reason (i.e., yours) for the behavior to occur as it did. Otherwise your results would not necessarily point future theorizing in some specific, new better direction. Finally, keep in mind that the best experimental designs always enable something productive to be said no matter what results occur. Always spend enough time thinking through how competing models articulate at each point and try to find a procedure which reveals what happens in the case where the theories make opposite predictions. That way you will have something positive to say no matter what happens. For example, pecks to the right support one theory, pecks to the left support the alternative theory, while no pecks support a third theory and pecking both support a fourth theory. Even though this example is a bit extreme, it focuses attention on the importance of enumerating every possible outcome and considering what you will do for each possible outcome before you start the research.

Doing research in this way is a very powerful methodology because the results always bear on the paradigm. You will be able to publish the results no matter what happens. In a sense, "negative" results simply mean that the researcher didn't sufficiently plan ahead. Well-planned experimental designs are a necessary methodology for dissertations because no matter what, you will be able to have something to say and get your dissertation accepted, graduate, and not have to start over.

i. A Priori Prediction Based on Intuition

The core deductive prediction underlying your research can be based on your intuition, e.g., "I don't know why, but I'll bet the subjects will do xxx if the environment changes to yyy." We often have knowledge we can't clearly articulate (which is perfectly OK). When our intuition is at variance with accepted knowledge, we have the opportunity to do research, which will either better the field or better ourselves. The only issue is that you may not know how to put your results into some context. That context demonstrates the importance of the research, gives conceptual support, establishes the validity of your interpretation, demonstrates that your results were reliable, and enables you to capture someone else's interest in the research.

ii. A Priori Prediction Based on Theory

The underlying deductive prediction can be based on a theory that predicts a relationship, e.g., "if deprivation is increased then the relative rate to the easier alternative will increase."

iii. A Priori Prediction Based on Model (Quantitative Theory)

The underlying deductive prediction can be based on a model that specifies an exact quantitative value, e.g., if the compound is reinforced, then the rate to the stimuli when presented in isolation will decrease by half."

b. Post Hoc Realization of Functional Relationship

Very often data are generated in an experiment that provide information in addition to simply supporting or refuting a specific deductive prediction even though the experiment had been specifically designed to only reveal a particular functional relationship. Functional relationships other than those of our original interest may be discovered in the data from a design that had only been intended to simply evaluate a prediction. We should make the most of the work we put into doing research by getting every possible piece of information out of it. The more the additional research and analytical effort this post hoc activity requires, the more this aspect of deductive research becomes inductive research.

2. Inductive or Dynamic Research Approach

This second class of research begins from some observational or experimental result and attempts to integrate the finding within some theoretical context. Whereas deductive research starts with a theory and implements a behavioral test, inductive research starts with a behavior of interest and searches for an integrated context.

Interesting or surprising results are usually those for which our explicit or implicit paradigm did not prepare us. Therefore, our interest in some particular functional relationship may, at the bottom, actually, be the result of its support or refutation of some implicit paradigmatic expectation. As a result, the separation between deductive and inductive research can sometimes be a bit fuzzy, but in general, if you observe some behavior and wonder why, then you are doing inductive research.

a. Discovery Via Post Hoc Organization of Data

i. Comparison of Results to Known Functions

This approach to inductive reasoning is analysis, or reorganization of data with the intent to determine whether or not it matches well-known or predictable relationships. This type of "playing" with the data has particular regularities in mind. You analyze your data looking for specific functions. These attempted solutions could be generated by theories, models, or even intuitions.

ii. Description of Functional Relationship

Very often things happen in an experiment for which you have no preexisting knowledge and no particular "ax to grind." Functional relationships other than those previously documented may be observed. In this case your primary task is one of accurately and completely describing and illuminating a phenomenon whose larger context and set of controlling factors you can only guess. As a result, the next step in the research program would be the construction of a broadly based functional context as detailed below. For the most part, this is clearly and completely illuminating existing data so that you or other researchers can take the next step in understanding what's going on.

We can have a hunch about the ultimate nature of the functional relationship and analyze and display our results to best point toward that speculative function or we may be able to formalize our intuition into a general theoretical model that makes qualitative predictions and is falsifiable.

b. Discovery Via Construction of Functional Context

This general approach to inductive research, not only reorganizes data to clearly illuminate what's there, but also carries out specific experimental procedures in order to better characterize the phenomenon of interest. It goes beyond a simple description of the revealed functional relationship by carrying out research with the specific task of enabling the specification of how that function changes with changes in procedures. Those procedures are specifically intended to reveal what are likely to be important causal relationships. In essence, you are saying "I don't know the final explanation, but here is how the phenomenon changes in three different situations that I think are revealing." Subsequently, the task is to integrate the phenomenon into a broad context. This approach reorganizes data but also does original research with the intent to explain the findings

B. Research Tactics

The following are some attitudes or tactics that are likely to bring you success in your research endeavor.

1. Be Committed

Nature does not give up its secrets easily. Choose a topic for which you will be willing to spend a great deal of time thinking about and working on. Have confidence in your own judgment (but, note #5, e., f., and g., below). Be enthusiastic. Work in a social situation that keeps you working and thinking. If necessary, create the social situation that will provide the reinforcers you need. Simply put: unusually great knowledge and insight, like unusually great muscles or unusually great musical skill, come from unusually great amounts of work.

2. Be Well Read

Building on the discoveries of others is very much more productive than reinventing the wheel. Reading time will pay off vastly more than "doing" time while it may take 40 hours of reading papers to clearly understand what needs to be tested, it is likely to take 400 or 4000 hours of experimentation and analysis to discover it yourself, and even more time if you have to redo it to fix your misunderstandings. Use reading time to get wisdom and to spark ideas. Use "doing" time to clearly prove that you were right or wrong so your thinking can move forward.

Recall that the master diagnostician House on television is a silly caricature,

little better than a wrestler. The only path to being the best diagnostician is to read vastly more medical journals than anyone else. To paraphrase the dictum, “measure twice, cut once”; "read ten experiments, do one".

3. Balance Novel and Mainstream

Strike a balance between following the existing paradigm with tried and true procedures and tried and true conceptualizations, and breaking new ground with new conceptual approaches. Old ground is safe but boring. New ground is exciting but very risky. The problem is similar to building a productive stock portfolio.

4. Focus on Productive Relationships

a. Reliable Robust Relationship

Independent variables that produce large effects or consistent effects are easier to measure, are easier to separate from random noise and confounds, and are more likely to indicate important relationships in nature.

b. Apt and Optimal Elements

Choose an optimal subject, apparatus, and procedure to research potential relationships. It is easier to use pigeons than whales as subjects. It is easier to detect an instance of a behavior that is a movement that activates a switch, than to detect the behavior of dipping of a wing in free space or the behavior of thinking some thought. The presentation of food to a hungry organism can be more reliably controlled than the control of “life’s little pleasures.”

c. Large Potential for Gain

Some pieces of knowledge are simply more useful than others. Articulating a functional relationship which dramatically reduces the complexity of the existing paradigm, or which is a counter example to a previously coherent paradigm; provides a greater step forward than some finding that only extends a well-established finding in some minor way.

5. Maximize Your Chances to Discover

a. Simplify to Essential Case

Discovery is much like mining and refining. First we must uncover a relationship and then we must separate the inessential and confusing from the actual effect. We want to eliminate the uncontrolled and unnecessary variability and extraneous details that obscures the important effect. It is a matter of signal-to-noise ratio in the information. In sum, the insightful use of simplicity is a very powerful research tool. It is often labeled research elegance.

b. Sort in Terms of Similarities and Differences

If you sort phenomena into positive and negative instances of something, even if you cannot articulate what that dimension is, then you can define a boundary that separates the two classes. That separation rule may allow you to understand something important about the phenomena.

c. Search for Regularities

Regularities provide you with a method of simplifying the booming confusion of nature. A single simple rule can extract or make comprehensible much of the obtained variance. For example, the fluctuating activity levels of an organism can be better understood by noting how it shifts with the light cycle.

d. Optimize Visualization

Some ways of characterizing complex relationships are better than others. Your task can be made very much easier with the right visualization, often a clear graphical depiction of a relationship simplifies its understanding. Analytical geometry was almost as great a step forward in our thinking as was language. It allows complex and subtle relationships to be seen as simple obvious spatial relationships. Instead of giving your readers a figure with a function that is less squiggly after a treatment and requiring them to extract the important change in variance in their head, give them a function that characterizes the actual variance (variance is on the *y*-axis rather than rate).

e. Be Open-minded

Be careful not to fixate on a judgment error and try to prove it at all costs. Sometimes what we strongly believe or hold dear turns out to be wrong.

f. Recognize Errors as Breakthroughs

If you make a wrong prediction either you discovered something you misunderstand about nature or you discovered something the paradigm misunderstood about nature. In either case, you have gained because you or your model will be better the next time.

g. Drop Everything if Necessary

While seeing a problem through to completion is almost always the only acceptable research methodology, occasionally, a finding of such great significance occurs that we should drop everything and pursue the new problem. It requires a clear understanding of the paradigm to understand the significance of important anomalous findings. Fleming discovered penicillin because he immediately understood the significance of a ring of dead bacteria around mold. He then dropped everything and concentrated on that effect.

6. Be Alert

It takes only a few moments to realize how many great discoveries are at their heart very obvious and straightforward enough for almost anyone to have been able to "discover"; if only the observer clearly understood what was expected in the situation based on existing knowledge and how the obtained result was clearly different. Consider, for example, the discovery of operant conditioning, reflex conditioning, and the antibiotic action of penicillin. Be alert and you too can discover paradigm-changing phenomenon.

7. Be ingenious

Artistic talent is the ability to put simple musical notes or marks on paper together to create something better than the vast majority of people. Scientific ingenuity is similar: it is the ability to see paradigmatic issues which have a high potential for gain, to have a knack for choosing apt and optimal procedures, and being able to see the important relationships between independent and dependent variables.

8. Be Relentlessly Focused

Knowledge will not be dumped squeaky clean and perfectly obvious into your lap. Your task will be like trying to find the dolphin in the preface; you will have to actively make it make sense. If the knowledge has already been discovered, someone can tell you where to look and generally what you should see. But when doing research, you are not trying to come to see what people already know; you are trying to discover something that no one before has ever seen or understood. It is far more difficult. If you are to be the first to see something, then no one can show you where to look and what you should see. You will have to discover it for yourself.

Some researchers have said that the discovery task is like the mental equivalent of passing a truck in the rain. In order to advance, you must enter and successfully pass through a period of intense confusion because the old answers are no longer appropriate. Success is not guaranteed. In fact, because nothing can guarantee that a solution is even possible, the confusion is intimidating and makes you want to stop or turn back. But if you make good decisions and stay the course, you pass through to clarity and you are much further ahead.

The intimidating power of confusion is easily illustrated by the difficulty of maintaining attention. Dividing three digits into six digits on a piece of paper is boringly simple. In your head, even two digits into four digits is difficult, and requires intense and continuous attention. The effort makes you want to stop. But, if you stay the course long enough to find the answer, that answer is an easy thing to remember and use. The difficult, scary, unclear, and bewildering challenge of discovering a conceptual solution to a new problem is sometimes referred to as "working your way through the fog of ignorance and confusion."

9. Be Diligent, Meticulous, Compulsively Accurate, and Scrupulously Honest

Keep in mind that, if other researchers are to use your data and interpretations when they build their theories (i.e., your reinforcer), then they must trust you implicitly. If your data were in error or if you were not correct in your inference, then their theory will fail and they will be considered foolish (i.e., their worst nightmare). People will buy Ebay items from someone with a proven record of honesty. People tend not to trust newcomers, and they are very wary of people with bad records. Your reputation is all you have; guard it well.