# The Experimental Analysis of Behavior

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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. 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 courses. The material covered in this text is not trivial. Education does not work like WalMart 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. 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 in figure P1 until you can see the embedded image.

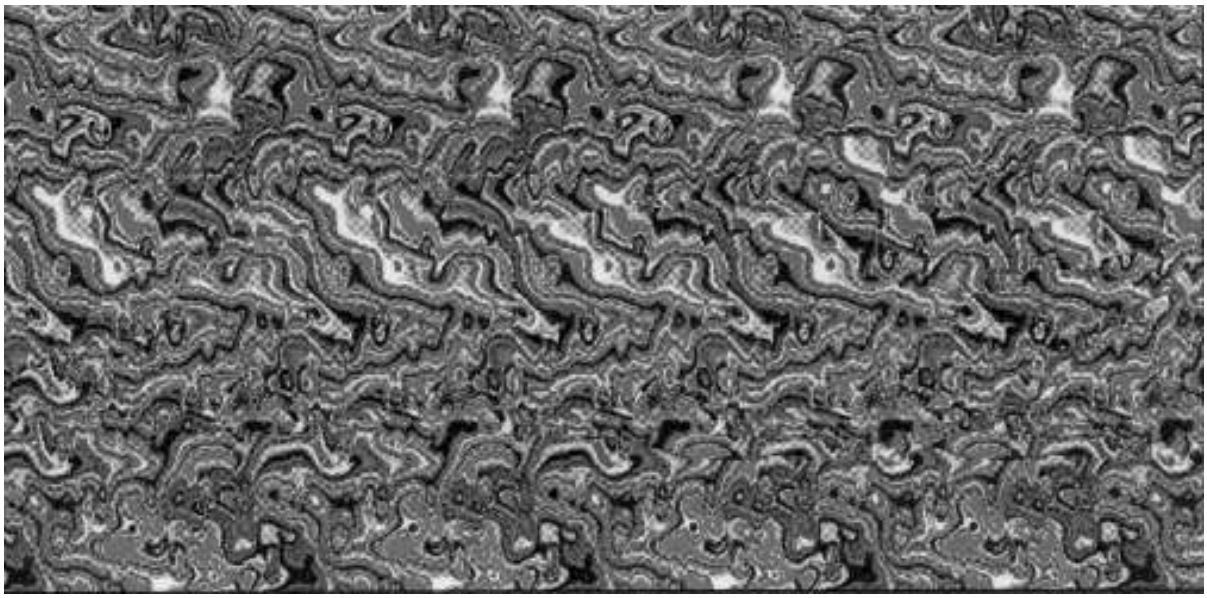

*Figure P.1 A single image random dot stereogram illustrating that an organizing principle(the dolphin) can bring order to apparent chaos (the squiggly blobs). Secondly, it illustrates that there is a difference between simply being able to repeat the organized principle and actually seeing or understanding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

### A. 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. 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.

# II. Behavior Analysis is a "Paradigm"; 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 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

### 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 they have to be true for the theory to work.

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.

### 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 higher-order functional relationships provided by the phone allow you to do things to your phone 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 "be taught" 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.

### 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 (i.e. "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 could be characterized, 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. **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 as the result of covariance 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's behavior when a bell is repeatedly followed by meat powder (i.e., Pavlovian reinforcement).

It is worth a few moments contemplation about this class of adaptation. It is often said that life is the most amazing process in the universe. Living organisms increase the rate of beneficial events and decrease the rate of negative events as the result of their experience with those events. If life is seen as a vehicle moving through nature, then adaptation is the steering mechanism. Adaptation can occur across a wide variety of levels and time scales. Behavior analysis is the discipline

that studies adaptation that occurs in an individual across the seconds to days time scale. For example, behavior analysis does not study the causes and results of evolution, rather it studies the causes and results of learning.

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 as the result of a shout 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 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.

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 or adaptation 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.

### 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.

## III. Regarding This Text

I believe that my task is to help you to actually understand the causal principles underlying phenomena covered by Psychology and Behavior Analysis (**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 concept: "reinforcement increases response rates" 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, but rather to enable people to understand nature which is to be able to predict, control, synthesize, and control it.

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 at your own pace. 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.

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 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 each 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 provide all the labels.

**3. 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.

**4. Many reviews are explicitly placed throughout the text.** Figures are often re-presented to save you the effort of searching for them. Don't skip over the material just because it seems familiar.

**5. The class meetings will initially be interactive question and answer sessions pertaining to the review material 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 importance of the one on one answer as opposed to a group lecture is well illustrated by imagining ten individuals trying to master their piano playing by listening to a class lecture. Besides, at some time in your future career your advancement will depend on your being able to read and understand something on your own without your supervisor explaining it to you.

**6. The first eight chapters should be seen as a quick simplistic review for context rather than critical course content.** The review is to assure that everyone has a sufficient background to meaningfully participate in the class discussions. For the most part, the course is interactive discussions of a

sample theory and the subsequent student presentations with their Q&A.

**7. The sample theory is exactly that, it is <u>not</u> revealed truth**

The sample theory presented in chapters 9, 10, and 11 is one attempt to bring a structure to as much short time scale adaptation as possible. Corrections are inevitable and ultimate success of the theory is not a given. This is an opportunity to use and practice what you learned in Conceptual Foundations. Even though the material in chapter 9 is also a review its details will be important for framing your questions pertaining to the theory. Keep in mind that your questions could provide a needed adjustment to the sample theory. We will be doing what is nothing less than an essential aspect of how science works.

**8. 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 <u>expected</u> to have questions. Employees, on the other hand, are <u>forbidden</u> to be ignorant. Your task is to get rid of every shred of your ignorance 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 ignorance. Enable your faculty to do the thing they enjoy the most: explaining things. Get your money's worth, and then some.**

# 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. Be a behavior analyst on your self.

### 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.

### 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 if you answer the phone.

### 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 <u>immediate</u> 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

I would like to acknowledge the work of the scholars whose conceptualizations eventuated in this text. Firstly, the material on history, physiology, and innate behavior had their origins in material ideally conceptualized and written by the scholars in those areas as is indicated in the text. What started as annotated embellished study guides for supplementary texts which reviewed the necessary prerequisites for the main and actual point of this course, devolved into simple modified derivative versions of the original that did not require substantial outside reading assignments for the students. My role in those sections is as a musician playing music framed out by others with greater or lesser improvisations and alterations to their basic themes.

Secondly, I do not claim to have originated de novo the basic theoretical conceptualization of the present text. My knowledge base comes from reading the literature not ex nihilo. If I had lived a few thousand years ago, this text would be very different. In broad simplistic strokes the present perspective on short time scale adaptation is a simple derivative of: 1) **Herbert Spencer** for changing the focus of psychology from the decisions of the mind to what the organism learns to "be" (what came to be labeled short time scale adaptation); 2) **Ivan Pavlov** and **Edward Thorndike** for the identification of the procedures and relationships for clearly demonstrating that process with what came to be labeled Pavlovian and Thorndikian conditioning; 3) **John Watson** for making science de rigour in psychology 4) **Fred Skinner** for evolving psychology into a hard science by establishing the rigorous and principled paradigm of Behavior Analysis; 5) **John Donahoe** for pointing out that Pavlovian and Thorndikian contingencies are necessarily inseparable; 6) **Bob Rescorla** for demonstrating that correlation can be considered the cause of short-time scale adaptation; 7) **John Gibbon** for documenting that the second half of an interfood interval controls terminal responding; and 8) **Elliot Hearst** and **Herb Jenkins** for conceptualizing behavior as bipolar.

Finally, I would like to thank the students and colleagues who over many semesters have contributed to making the text clearer, more comprehensive, and more authoritative with each revision. Their feedback has been both the catalyst and reinforcer for the evolution of this text.

# CHAPTER 1

# The Epistemological Foundations of the Experimental Analysis of Behavior

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

A. What is a paradigm?
B. Why is the existing paradigm always presumed to be correct?
C. A paradigm's description of reality must in some ways be considered as more fundamental than direct experience
D. Why are there rules and why must we follow them?

## II. The Functional Relationships That Are, and Are Not, the Focus of EAB

A. Level of analysis or molarity of the paradigm (unit domain)
   1. Cellular adaptation
   2. Organismic adaptation
   3. Group adaptation
B. Time scale of the paradigm or hysteresis of adaptation (time domain)
   1. Immediate time scale adaptation
   2. Short time scale adaptation
   3. Medium time scale adaptation
   4. Long time scale adaptation

## III. The 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)

## IV. What is an Understood Fact?

A. 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
g. Coda: truth and reality versus opinion and delusion

B. Demand 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

## V. To What Does "Information" and "Knowledge" Actually Refer?

A. Conceptual precursor: Knowledge or information as covariance or accountable variance
1. Covariance depicted as a scatter plot
2. Covariance depicted as a Venn diagram

B. Classes of information transmitted by accountable variance
1. Cause-effect interpretations
2. Description only interpretations

C. Potential reaction strategies to residual variance, error, or ignorance
1. Experimental solution
2. Withheld judgement
3. Assumption of “true score” and random error
4. Delegation of the problem of residual variance
a. Acceptable delegation
b. Unacceptable delegation

## VI. Conceptual Follow-up: The Task of Research is to Find and Understand Covariance

## VII. Issues Pertaining to the Adequacy of the Information / Knowledge Obtained by Research

A. Structural information: characteristics of the immediate time scale reaction or the capacity of the organism

B. Functional information: the functional relationships governing the emergence or governing the expression of a behavior

## VIII. What is an Explanation

A. Delimiting an explanation
   1. Epistomology
   2. Domain
   3. Type of covariance
   4. Paradigm of the field
   5. Local context or specific research area

## IX. Evaluation of Explanations, Theories and Models

A. Unequivocally deterministic
B. Explicit / unambiguous
C. Non tautological
D. Externalistic
   1. The mind body quagmire
      a. Not "biological as opposed to psychological" (i.e., body versus behavior)
      b. Exclusive focus on behavior, the body is irrelevant
   2. Conceptual follow-up: behavior analytic externalistic conceptualization of causation and explanation and the passing over in silence the unproven or the unprovable
E. Functional properties
F. Integration within the behavior analytic and scientific paradigmatic context
G. Minimal error
   1. Parsimony in explanations, theories, and models
   2. Generality in explanations, theories, and models
   3. Conceptual follow up: optimal tradeoff
H. Quality of prediction
   1. Validity of explanations, theories, and models
   2. Reliability of explanations, theories, and models
   3 Percent variance accounted for by explanations, theories, and models
   4. Minimal free parameters
   5. Elemental predictions and emendations
   6. Confirmable
   7. Falsifiable / risky prediction / information transmitted
I. Principled / testable
J. Understood facts and processes
   1. Analogies or metaphors versus understood factual elements and processes
   2. Folklore versus understood factual elements and processes
K. Productive

## X. Procedural Issues Pertaining to Short Time Scale Adaptation

A. Implementing Research and Evaluating Results
   1. Two basic stages in research design
      a. First: eliminate confounds from causal factors
      b. Second: separate true cause/effect from chance
   2. Two basic strategies of research design
      a. Null hypothesis significance testing (NHST): "groups design"
      b. Behavior analytic research strategy (BARS): "single-subject design"

B. Direct and indirect assessment of the adaptation of behavior
   1. The emergence, acquisition, or origin of behavioral adaptation to a change in conditions (direct assessment)
   2. Comparison of the asymptotic expression of behavioral adaptation in two different situations (indirect assessment)

C. Optimizing Research by optimizing its decision strategy
   1. Impact of Decisions by "Whim," "Guess," or "Intuition" (Eclecticism)

D. Optimizing Research by optimizing its elements
   1. Optimized or apt subjects
   2. Optimized or apt apparatus
   3. Optimized or apt procedure

E. Optimizing Research by Optimizing its Properties
   1. Maximization of Reliability
   2. Maximization of Analytical Detectability
   3. Maximization of Paradigmatic Detectability
   4. Maximization of Generality
   5. Maximization of Meaningfulness

# CHAPTER 1

# The Epistemological Foundations of the Experimental Analysis of Behavior

This chapter is a review of the conceptual foundations of the behavior analysis paradigm in order to refresh that material and provide a comprehensive context for the presentation of the Experimental Analysis of Behavior material.

## I. Paradigms: The Optimizing Mechanism Underlying the Evolution of Our Understanding of What We Label Reality i.e. Science

### 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. 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 whenever some scientists are unable to figure something out.

In review, We accept our paradigm as "reality" because our paradigm is based on everything we know and our paradigm is consistent with everything we experience. Simply put, our paradigm is our most valid and reliable explanation of everything.

### C. 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 paradigm itself.

### D. Why are There Rules and Why Must We Follow Them?

We have all had, at first blush, a desire to have the freedom of discretion, so that we can do what we want when we want. It takes only a moment to see deep flaws in that simplistic desire. What about stealing money for a great vacation, selling a car with bad brakes, dumping toxic waste into a reservoir, or lying in a courtroom?

The proper practice of medicine can be seen as physicians playing by the rules of best practice using the treatment with the best proven record of success rather than a whim. The rationale for always following the rules may best be illustrated by professional gambling which is when people who play by the rules of chance harvest money from people who play by intuition. The fact is a 7 is the best bet in dice even though it doesn't win every time "Rules" are the well thought out procedures that have been proven to generate the most favorable outcomes of all those that could happen.

The practice of science or behavior analysis is similar. You must follow the rules that were developed to assure that you get to the truth or get the job done right as often as is possible ..... even if it's more difficult than simply "winging it" "just this once".

The success of behavior analysis is the result of its unrelenting insistence on following the rules of science.

*You can say that again*.

## The success of behavior analysis is the result of its unrelenting insistence on following the rules of science.

The failure with much of classical psychology is that it has rules that are unscientific or it looks the other way when its practitioners "wing it". Do not

depend on a practitioner of psychology (or medicine, engineering, etc.) who avails themselves of the freedom of discretion to follow or not follow the rules that are designed to maximize getting to the truth. Simply making decisions based on intuition or discretion in the absence of science has simply not worked out. Simplistically put, don't drink the water from a cistern where the gate keeper does not worry about what gets put into it.

# II. The Functional Relationships That Are, And Are Not, the Focus of EAB

Not every possible measure of every possible phenomenon is of interest to EAB. Only those measures of short-time scale adaption in individual organisms are seen as relevant to EAB. The following material presents the paradigmatic context of EAB in order to better define what is, and is not, EAB, and to better define what class of functional relationships provide a useful and paradigmatically valid explanation. Invoking cellular adaptation, evolution, stimulus intensity, or mental processes as an explanation for short time scale adaptation is no better than space aliens or magic. To paraphrase Robert Frost, "being aware of and respecting the boundaries between paradigms makes good scientists."

### A. Level of Analysis or Molarity of the Paradigm (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 focuses on listening to and understanding the violin rather than all the instruments making up a symphony orchestra.

The most familiar changes in level of molarity are those from an individual versus a group. When measures are taken from a group such as their vote, 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. Cellular Adaptation

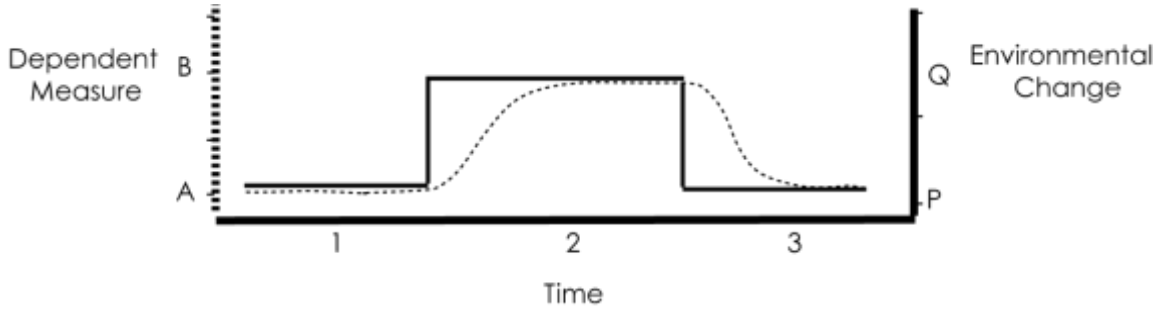


*Figure 1.1 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag the dependent variable changes to State B and 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 the dependent variable returning to State A and again coming into equilibrium with the independent variable at Time 3..*

Cellular adaptation (Figure 1.1) 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.

### 2. Organismic Adaptation

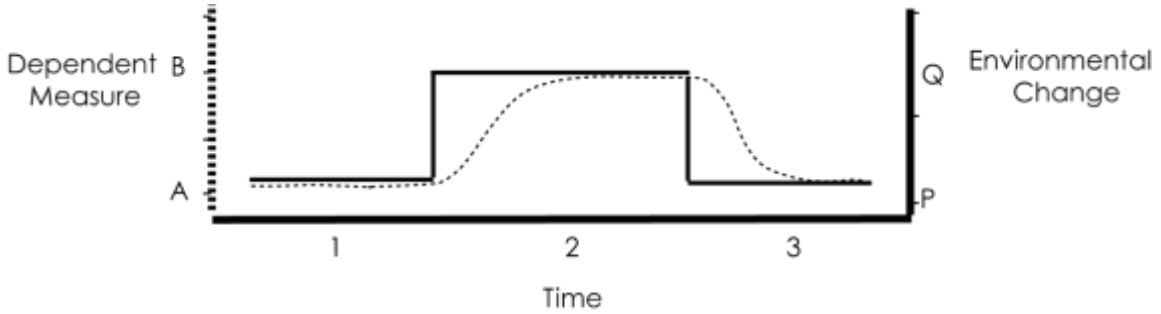


*Figure 1.2 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag the dependent variable changes to State B and 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 the dependent variable returning to State A and again coming into equilibrium with the independent variable at Time 3..*

This class of adaptation (Figure 1.2) involves the adaptation of the behavior of a whole individual 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 ("B"). University courses in this area are taught in the Psychology Department

### 3. Group Adaptation

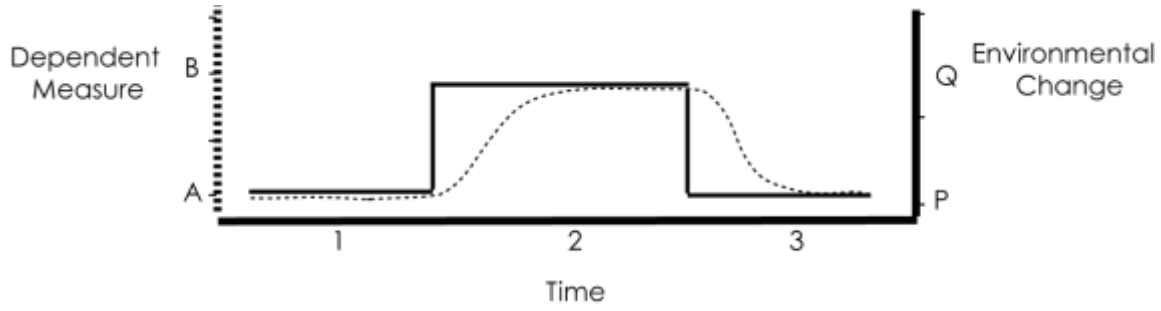


*Figure 1.3 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag the dependent variable changes to State B and 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 the dependent variable returning to State A and again coming into equilibrium with the independent variable at Time 3..*

Group adaptation (Figure 1.3) 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.

### B. Time Scale of the 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.

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 come into equilibrium or adapt to new environmental conditions.

#### 1. Immediate Time Scale Adaptation

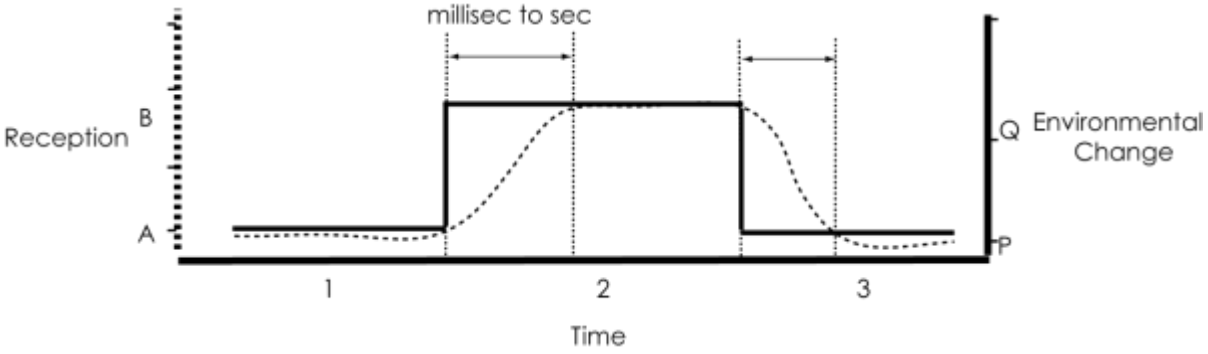


*Figure 1.4 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag in the milliseconds to seconds range the dependent 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-term adaptation (Figure 1.4) 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-term 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-term adaptation across evolutionary time, are both instances of immediate term 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 term adaptation could document the change in the probability of a reaction as a function of stimulus intensity. Often immediate-term 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).

### 2. Short Time Scale Adaptation

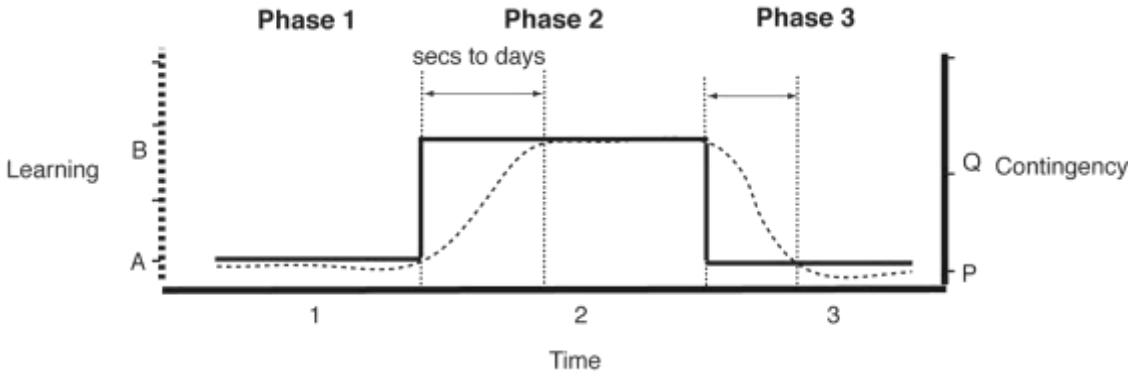


*Figure 1.5 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line); the independent variable changes from State P to State Q (Phase 2). Following a lag in the seconds to days range the dependent variable changes to State B and comes into equilibrium with the new value of the independent variable at Time 2; at some later time, the independent variable changes back to State P in Phase 3. 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 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 the 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 1.5 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 1.5 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 1.5 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 **adaptation of behavior to the schedule of reinforcement**. The adaptation takes a short time to develop and it perseverates for a short time after the conditions are removed.

In sum, As a result of correlations between antecedent events and subsequent outcomes, the functional properties of behavior are changed in a fundamental and semi-permanent ways. The details of those processes and resulting changes are:

1. The reaction to a neutral stimulus changes over the course of a seconds-to-days time scale as a result of a correlation between antecedent events and

subsequent outcomes. Where stimulus *x* had resulted in behavior ∝; following the correlation, the same stimulus, *x,* results in behavior β. This capacity is well beyond most simple input output systems. This change is illustrated in Figure 1.5 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.

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 ∝ and not behavior β. This is illustrated by the hysteresis of the dependent variable in Figure 1.5 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.

### 3. Medium Time Scale Adaptation

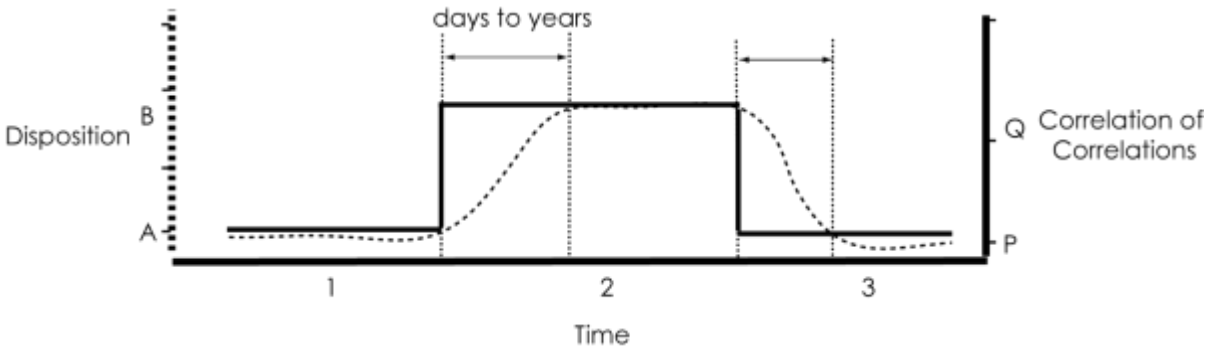


*Figure 1.6 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag in the days to years range the dependent variable 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 prototypical exemplar of medium-term adaptation (Figure 1.6) 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-term 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 functional relationship rather than simple immediate term 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 term adaptation is a virtually permanent change in behavior or the emergence of a "disposition." The independent variable for medium-term 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 1.7 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-term 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 1.7 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.*

### 4. Long Time Scale Adaptation

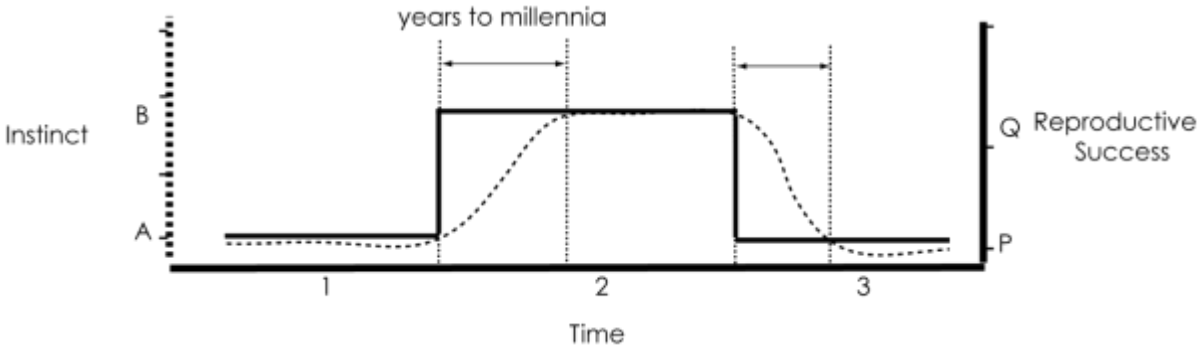


*Figure 1.8 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag in the years to millennium range the dependent 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 long-term adaptation (Figure 1.8) 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-term 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

# III. The 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 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." or "how much money will you make with it." 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.

# IV. What is an Understood Fact?

### A. 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.

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.

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. 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 following principles have been very useful in separating truth from fiction. Each is presented in its most straightforward version.

##### 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. 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).

### 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.

### 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.)

### d. Consistency with the Paradigmatic Framework Labeled Science

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. 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.

### 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.

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.

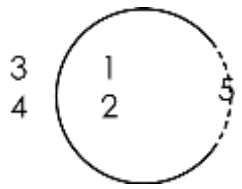


*Figure 1.11 Set notation which illustrates the importance of clear boundaries. Numbers 1 and 2 correctly belong in the set. Numbers 3 and 4 are correctly placed outside the set. It is not currently known whether Number 5 should be placed inside or outside the set*

The meaning of a word is intended to include some elements and exclude others. In the case illustrated in Figure 1.11, 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.

### 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.

## B. Demand 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.

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...."

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.

### 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. 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

#### 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.

### 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 1.12 illustrates that issue.

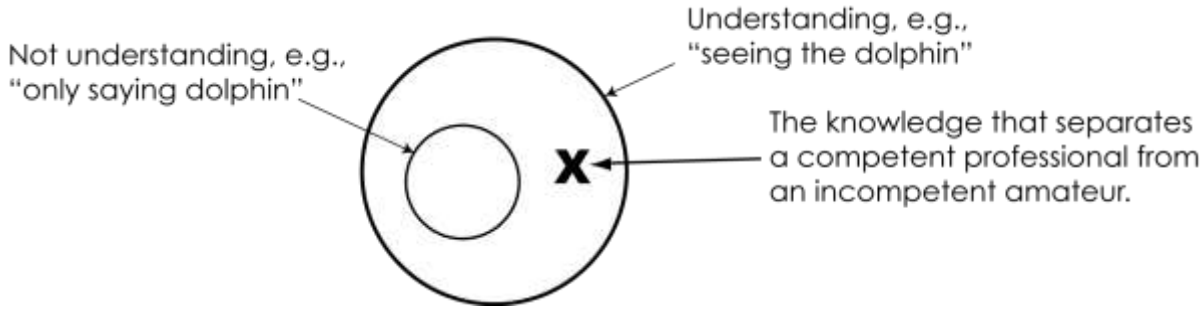


*Figure 1.12 Understanding is substantially more than simply repeating the words used to label a thing. Understanding is also to be able to behave correctly with respect to the issue in a wide variety of circumstances.*

# V. To What Does "Information" and "Knowledge Actually Refer?

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: Knowledge or Information as Covariance or Accountable Variance

### 1. Covariance Depicted as a Scatterplot

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 1.9). 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 figure 1.9 below.

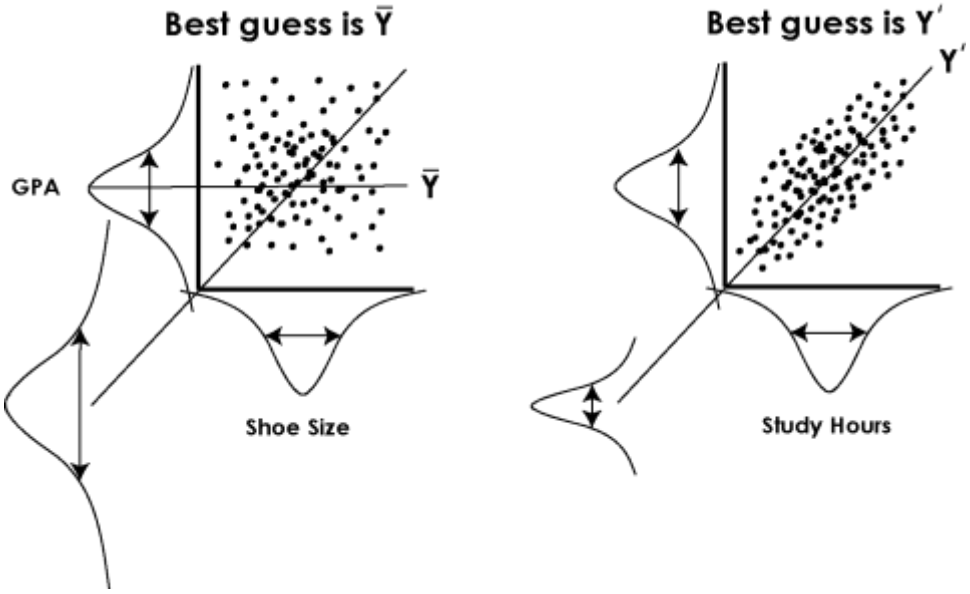


*Figure 1.9 The left and right frames show scatter plots (with stylized values and relationships). The left frame shows no relationship while the right frame shows a moderately high relationship. Both frames have the same distributions on the x and y-axes. The frequency of each value along the x-axis 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.

### 2. Covariance Depicted as a Venn Diagram

The two relationships depicted in Figure 1.9 as scatterplots can be illustrated in yet another way to emphasize percent variance accounted for. Each circle below (Figure 1.10) 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 1.10 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.

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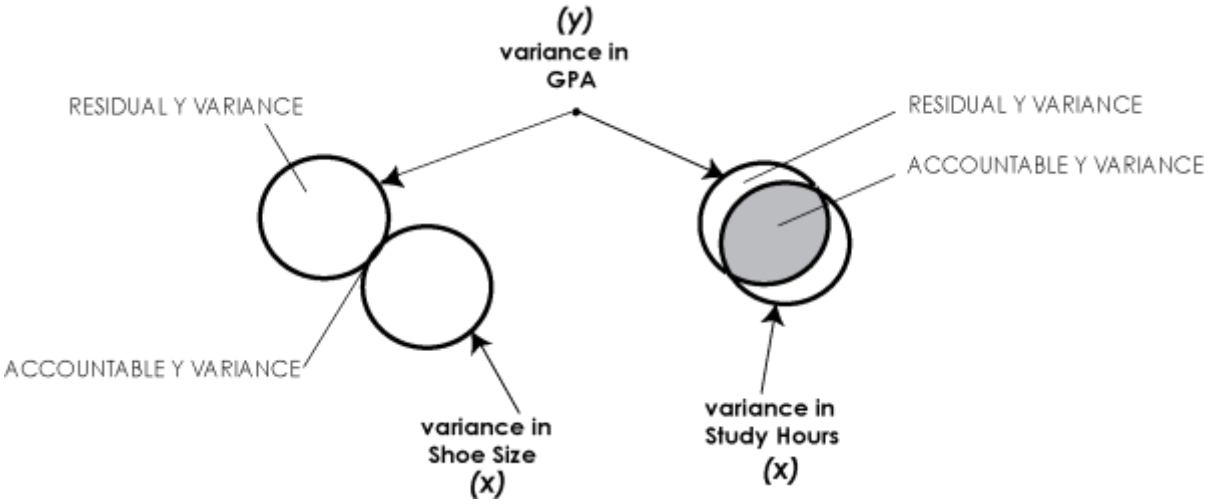


*Figure 1.10 The variance across the x and across the y-axis in each frame of Figure 1.9 is illustrated as a circle. Note all four circles are the same size just as the four distributions are equal. This figure has Venn diagrams illustrating variance accounted for as the intersection of the data on the 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. It's as if study hours takes a big bite out of the variance in the grade point average.*

### B. Classes of Information Transmitted by Accountable Variance

In the Venn diagram depiction of covariance in Figure 1.10, 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.

#### 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.

### C. 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 1.9 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." 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.

## VI. 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.

## VII. Issues Pertaining to the Adequacy of the Information/Knowledge Obtained by 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-term 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-term 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.

## VIII. What is an Explanation

A "description" details aspects of an event, e.g., the pigeon pecked the key 25 times; Johnny ran across the room. "Prediction" is the correct description of something which has not yet occurred, e.g., the pigeon will peck 25 times; Johnny will run across the room. "Cause" most typically but not necessarily specifies the necessary or sufficient event or events that immediately preceded the resulting change in behavior, e.g., because the spider fell on his arm, Johnny ran 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 anything from the relationship, spider or no spider on the arm and running or not running across the room, or between the size of the spider and how fast Johnny runs across the room, to the relationship between the mean weekly atmospheric temperature and the number of children attending school or the relationship between social status and wealth. Knowledge is a more general term than cause.

"Explanation" is more than knowledge and more than the simple immediate cause of something. Explanation is the specification of the context within which a causal relationship exists such as the ancillary factors necessary and/or sufficient for the cause-effect relationship and how the relationship will change with changes in the context, and why. The effect being explained and its causal factors are seen as exemplars of general processes and the particular events are only one of many similar cause-effect relationships. Obviously, the data being explained and the data used to develop the explanation must all meet the requirements of a science.

A paradigmatic framework is necessary to provide the context necessary for acceptable explanations. In fact, a paradigm can be said to come into existence when a group of investigators is interested in the same sort of phenomena and accept the same types of explanation. In that sense, adequate explanation within a paradigm is, to a degree, determined by the curiosity of the pioneers of that subsequently popular paradigm. Curiosity led those individuals to particular questions and the satisfaction of their curiosity determined their explanatory system, for example, the importance of the consequence of a behavior and the externalism of Behavior Analysis. To the degree that their choices were revealed to be productive, then the paradigm prospered. To the degree that their choices were unilluminating, the paradigm was likely to have declined and to have been replaced.

Theories or models are formal systems that are thought to produce outputs like the empirical system of interest. Whereas logic and mathematics are axiomatic and do not assess their validity via empirical referents, theories or models necessarily do. Correctly predicting aspects of the theory's or model's empirical referents is their raison d'être. 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. Explanations necessarily must be able to make predictions. Any explanation that could not generate testable predictions would not be a meaningful explanation because it could not be empirically evaluated.

While most typically, theories and models start with elements and processes

and predict data, explanations start with data and provide elements and processes. The three terms (i.e., theories, models, and explanations) have substantial shared meaning and are evaluated with the same criteria.

**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**

Explanations are one of the products of science and are a special case of language. To explain within the scientific paradigm is to provide the causal factors pertaining to a phenomenon and integrate the phenomenon within a larger context or paradigm. The explanatory context can be more or less comprehensive in its integration of time scales or levels of molarity. Recall that an explanation is not simply the description of an immediate time scale effect. 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. An explanation for an event brings to bear a wide variety of multiple converging supporting evidence by pointing out how that particular process or relationship is only one of a great many similar ones that can be said to follow the same rules. Obviously however, what is considered an explanation at one time may not be an adequate explanation in the light of new challenges.

### A. Delimiting an 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. Useful explanations must 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. 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 even 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.

## IX. 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.

### 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.

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.

### B. Explicit / Unambiguous

An explanation, theory, or model and its data must be explicit. 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.

### C. Nontautological

No aspect of an explanation, theory, or model can be tautological. . 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. . 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

**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. This approach 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 explanations in behavior analysis are those that provide the specification of the empirical environmental variables that control when and how a behavior emerges or is expressed across the short time scale 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. This is illustrated in Figure 1.13.

*Figure 1.13 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 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

*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).

Recall the anecdotes given in the preface: 1) the movement of the single neuron organism, 2) the egg retrieval of the herring gull, and 3) the operation of a smart phone. Each case illustrates a focus on the external controlling functional relationships. The internal mechanisms are irrelevant.

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.

### 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?" We cannot suggest that biological changes such as muscle movement 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. Our explanations need not consider the biological mediators and radical behaviorism considers them irrelevant to a complete explanation, but that does not imply that they are known to not be involved, and it does not imply that learning can be defined **as opposed to** a change in the body.

#### b. Exclusive Focus on Behavior, the 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. Conceptual Follow-up: Behavior Analytic Externalistic 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 ever had anyhow.

### E. 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.

### F. 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.

### G. Minimal Error

The issue of error is fundamental to explanation theories and models. The upper portion of Figure 1.14 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.

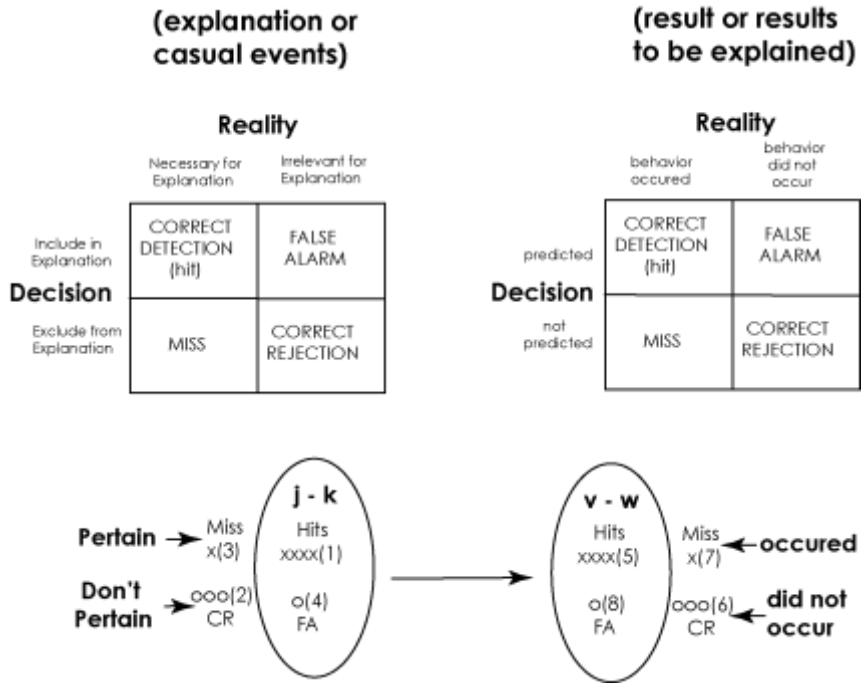


*Figure 1.14 A decision analysis conceptualization of an explanation, theory, or model. The upper section provides the decision analysis contingency table while the lower section provides a set diagram illustration of the causal events and results to be explained with decision analysis labels.*

Science is the process of developing more correct or more perfect boundaries for the two sets illustrated in the lower portion of Figure 1.14. 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 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 1.14.

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.

### 3. Conceptual Follow-Up: Optimal Tradeoff

There are two types of errors that the explanation, theory, or model can make (left side of Figure 1.14), and two types of errors pertaining to the results or data (right side of Figure 1.14). 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 [ 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).

## H. Quality of Prediction

### 1. 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.

### 2. 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.

### 3. Percent Variance Accounted For by 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.

### 4. 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.

### 5. 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.

### 6. 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.

### 7. 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 in figure 1.15. 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 1.15 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 1.15. 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 1.14. 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.

### 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 1.14 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.

### J. 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.

### 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 nothing more than a rough resemblance to their target. 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

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 necessary connection to nature or the essential "semantics". For example, 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." This is a hydraulic metaphor with substantial support as an explanation of hydraulic lift racks in auto repair shops, but no support for being applicable to the behavior of people. 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, which is, not really rocket science. Unfortunately, they are so caught up in the intuitively obvious validity of the physics of a hydraulic mechanism that they forget to ask if it actually applies to human behavior.

### 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 and when 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.

## K. 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.

# X. Procedural Issues Pertaining to Short Time Scale Adaptation

### A. Implementing Research and Evaluating Results

#### 1. Two Basic Stages in Research Design

##### a. First: Eliminate Confounds from Causal Factors

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.

##### b. Second: Separate True Cause/Effect from Chance

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.

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.

#### 2. Two Basic Strategies of Research Design

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

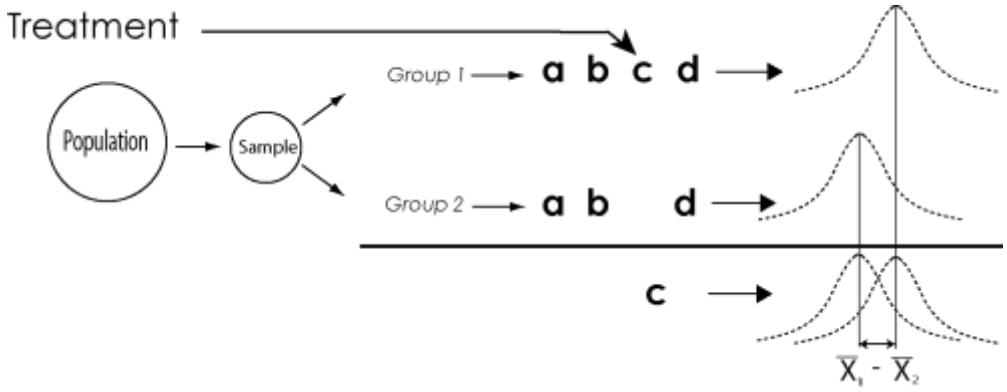


*Figure 1.16 Depiction of traditional group design research. A sample is drawn from a population and is subsequently sorted into two groups. The difference in the procedures these two groups are exposed to, in this case "c", causes the difference in the means of the dependent measure (i.e., $X_1 - X_2$) (if chance is not the cause).*

As depicted in Figure 1.16 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.

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

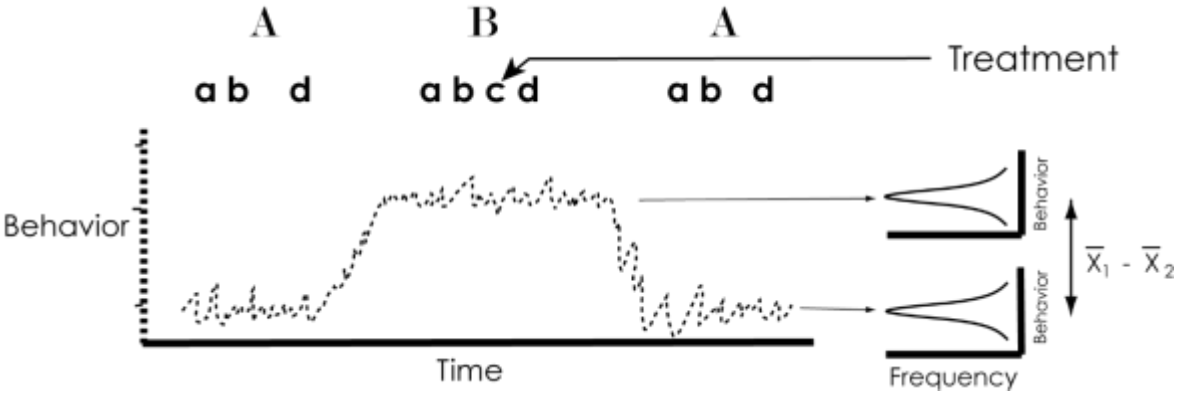


*Figure 1.17 Depiction of single-subject research design. An individual's dependent measure across time is shown in the left portion of the figure. The behavior before the treatment or during baseline is indicated in the left portion of the figure (labeled A). During the treatment conditions (B), the 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 1.17). 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.

## B. Direct and Indirect Assessment of the Adaptation of Behavior

### 1. The Emergence, Acquisition, or Origin of Behavioral Adaptation to a Change in Conditions (Direct Assessment)

This is the procedure used to define time scales of adaptation. It is the direct and at least at first blush, the most obvious method of assessing adaptation to some changed procedure.

The emergence measure illustrated in Figure 1.18 is the transition from some procedure considered a zero state to some asymptotic performance, to a different procedure. The difference in the behavior is attributed to the difference in the procedure. It is an x-axis measure as well as 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). It would be labeled a behavior dynamic.

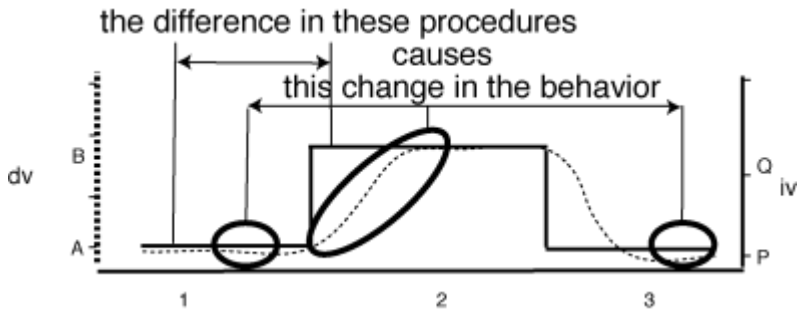


*Figure 1.18 This figure depicts the emergence or acquisition in a dependent variable (dotted line) as a function of a change in the independent variable (solid line). In sum, the change or difference in the dependent measure is caused by the difference in the independent variable. The initial state of behavior (in the absence of the treatment) is seen to be recovered at Time 3 when the independent variable is removed.*

### 2. Comparison of the Asymptotic Expression of Behavioral 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 equilibrium / 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 1.19. 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 procedure is a comparison of two procedures.

In Behavior Analysis, the interest is often on assessing how an asymptotic immediate-term reaction is expressed under two different short time scale contingencies. For example, learning could be studied by documenting a reaction or the asymptotic expression of a behavior (immediate-term 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.

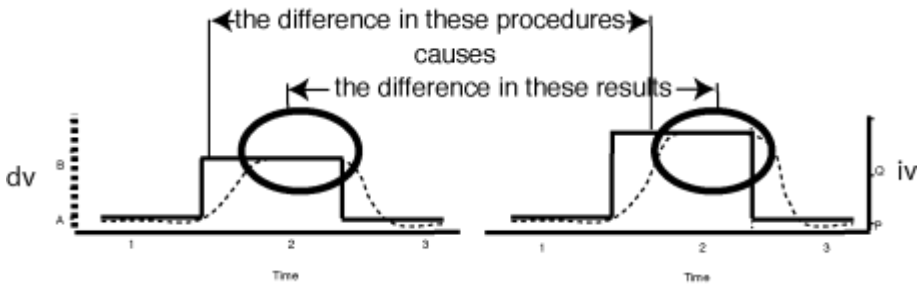

*Figure 1.19 This figure depicts the difference in the asymptotic expression or performance of a dependent variable (dotted line) as a function of a difference in the independent variable (solid line). In sum, the difference in the dependent variable is caused by the difference in the*

### C. Optimizing Research by Optimizing its Decision Strategy

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.

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

Eclectic decisions are unprincipled; they are made on the spur 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 explanation 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 a 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 in the first place.

The unacceptable fundamental flaw 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 (for obvious reasons). There is little likelihood progress will speed up in the future.

In sum Eclecticism:

1. has no systematic framework with which to organize results.

2. has no systematic rationale for decisions, therefore no principled cumulating path to a best solution.
3. makes it impossible to isolate why incorrect decision occurred and therefore, no systematic advance is possible.

### D. Optimizing Research by Optimizing its elements

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 together best together reveal the laws of nature while at the same time are easy to use and inexpensive.

#### 1. 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-term research is impossible) and require auditory or special cues because they have poor color vision.

#### 2. 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.

### 3. 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.

### E. Optimizing Research by Optimizing its properties

#### 1. Maximization of Reliability

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 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. The existing knowledge base could be wrong or the new research finding could be wrong. All other things being equal, the existing database and conceptual scheme is always given the benefit of the doubt.

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.

#### 2. 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.

### 3. Maximization of Paradigmatic Detectability

Sometimes people assert that if the scientific process were not so demanding about how to carry out science, we could discover more. Some hope that by decreasing the demand for having and following rules, we would increase the likelihood of arriving at subtle knowledge, but this is both true and false. It will make it possible to find better information but it will also dramatically increase the likelihood of arriving at wrong information (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. Unsystematic research or sloppy research cannot be justified simply by claiming that it will decrease misses. It is rather like a card game in which you have a jack, you can discard the jack and draw a new card but the probability is that you will draw a lower card.

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 they could reveal a fundamental weakness in the paradigm, but 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.

### 4. Maximization of Generality

To say something is generalizable is to say that the functional relationship applies to different situations. The functional relationship has external validity if different subjects, apparatuses, or procedures produce the same results. The original functional relationship is said to generalize to those 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 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 predicts in a new situation, then it is said to generalize.

The generality of a finding refers to the degree to which a functional relationship obtained in one situation is able to predict the relationship that occurs in a different situation. 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 ability to generalize information from one situation to another is a function of several factors. The reliability and validity of the original information the paradigm's validity (how well the paradigm matches all applicable functional relationships in nature); your understanding of the paradigm and the actual determinants of the behavior; and the relevant details of the original source of the data and the situation to which it is to be applied (i.e., the dimension of similarity between the situations in question.

A paradigm must not only provide a way to separate reality from illusion, but must also provide a way to generalize its functional relationships, for example, precisely how do we know that singing and cheers are similar to pecking and food and that the key pecking functional relationship will generalize to singing and cheering. What if we used long dead fish to reinforce singing people?

In sum, knowledge can be generalized 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 maximize generality, and 2) research emphasizing the understanding of the relevant paradigm, as many of the mechanisms of action involved in the original experiment as possible, the relevant details of the model and target, and understanding the dimensions across which that generality would be expected to occur.

"Similarity" research is often done in the "real" world with "real" people or at least primates while "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.

"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. Unfortunately, they typically introduce many confounds which seriously undercut the actually obtained generality, as well as limit the information they produce.

The raison d'etre of synthetic subjects or settings is to maximize our ability to understand the true causal factors and thereby maximize the generality of the obtained functional relationships. Unfortunately, synthetic subjects and settings could fail to produce generalizable information due to misunderstood or unaccounted for differences between the model and target.

### 5. Maximization of Meaningfulness

Simply put, from the data analysis perspective the research must account for the highest percent of variance in the obtained data possible. From the paradigmatic perspective, the research should enable the paradigm to explain the largest amount of variance in nature possible.

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.

# CHAPTER 2

# Causal Processes More Molecular Than Organismic Adaptation

## I. Introduction

## II. Existential Adaptation

## III. Atomic Adaptation

A. Inorganic molecules
    1. Water
B. Organic molecules
    1. Hierarchy of organic elements in living matter
    2. Carbohydrates (HOC)
    3. Proteins (HOCNS)
    4. Nucleic acids (HOCNSP)
        a. RNA
        b. DNA
C. Mechanisms underlying molecular interaction
    1. Assembly
    2. Disassembly

## IV. Cellular Adaptation

A. The evolution of complex functional relationships through recursive hierarchical control mechanisms
B. Evolution of vegetative cellular adaptation
    1. Vegetative or hormonal integration and adjustment in plants
    2. Vegetative or hormonal integration and adjustment in animals
        a. Hormonal coordination of integrative processes in animals
            i. Phermones
    3. Conceptual overview: trends in the elaboration of hormonal integration in animals
C. Evolution of animative cellular adaptation
    1. Information gathering
    2. Execution of action
    3. Coordination
    4. Conceptual overview: trends in the elaboration of coordination in animals: the nervous system
        a. Condensation / development of ganglia

b. Cephalization
c. Differentiation
d. Development of giant nerve fibers
e. Grouping and specialization of function
f. Recursive hierarchical control of control systems

# CHAPTER 2

# Causal Processes More Molecular Than Organismic Adaptation

## I. Introduction

This chapter provides a very short simplistic overview of the class of functional relationships below organismic adaptation in molarity. They are depicted as the three gray columns in Figure 2.1. This chapter should give you: 1) unshakeable confidence that there is nothing but materialistic causation at these levels of molarity, and 2) an understanding of what functional relationships are neither a target of research in EAB nor a source of explanations.

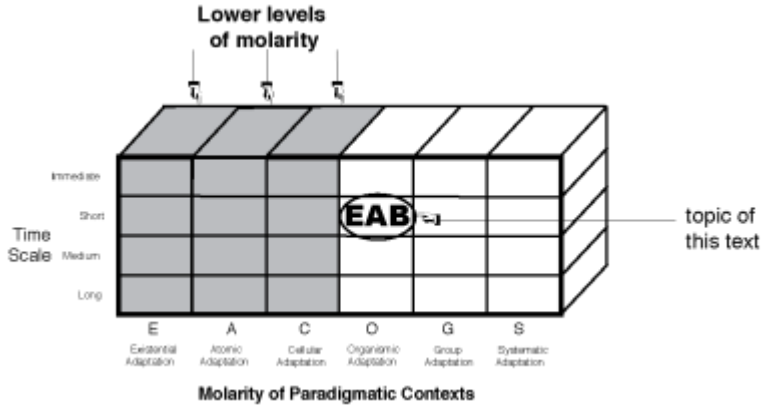


*Figure 2.1 Figure showing the relationship to EAB of the adaptation of levels of molarity below organismic adaptation (i.e., existential, atomic, and cellular adaptation) (highlighted in gray).*

Every action of every quanta, atom, and cell is caused by some natural process in the natural world. Each is a simple inevitable reaction of the environment to changes in other aspects of the environment. Hydrogen and oxygen combine to form water in the total absence of anything but materialistic causation. There is no need for mental processes, space alien intervention, or magical causation.

A useful precursor to this chapter is for you to look at some YouTube videos of kinetic art (the more complex the better). They are very simple inanimate mechanical systems that exhibit astonishing complexity. The key take home principle is that that astonishing complexity does not imply some homunculus is inside "knowing" and doing what needs to be done.

This chapter reviews and is based on the dated, but conceptually illuminating book, "Organic Foundations of Animal Behavior" by Joseph Altman (which is not to say he would have agreed with all of it). You really should read some current

physiological psychology text that is strongly focused on, and conceptualized in terms of the behavior of the organism as a whole (admittedly, they are hard to find).

# II. Existential Adaptation

All the different substances that exist in the universe are made up of only four fundamental forces: strong force, weak force, electromagnetic force, and gravitational force. Entanglement is a currently popular causal mechanism.

Few would attempt to argue that the activities of these forces are due to anything other than the strictest of materialistic causation.

# III. Atomic Adaptation

Everything that exists is nothing more than the four fundamental forces assembled into about 117 different elements which are in turn assembled into the millions and millions of substances in the universe. What makes all of the bewildering variety of various substances in the universe different is nothing more than which of the meager 117 elements are involved and how they are combined.

Again, very few would attempt to argue for any but the strictest materialistic causation when discussing atomic adaptation.

Living cells are made up of organic (compounds containing carbon) and inorganic (compounds not containing carbon) constituents.

### A. Inorganic Molecules

#### 1. Water

Water is a very important constituent of organisms.

1. High solvent capacity
2. High heat capacity - can absorb much heat when it evaporates
3. High heat of vaporization - carries off much heat
4. High dielectric constant - functions as good dispersing agent for electrolytes
5. Can participate in many biochemical processes

### B. Organic Molecules

Carbon has four valence electrons that can be lent to, completed by, or shared with others. Carbon can combine with metallic and nonmetallic substances as well as other carbon containing compounds.

The bonds are strong and carbon can therefore serve as a structural framework for very large molecules.

#### 1. Hierarchy of Organic Elements in Living Matter

A simple diagram of the increasing complexity of constituents is seen in Figure 2.2. Note that each increasing level of complexity simply adds a single element to the substance.

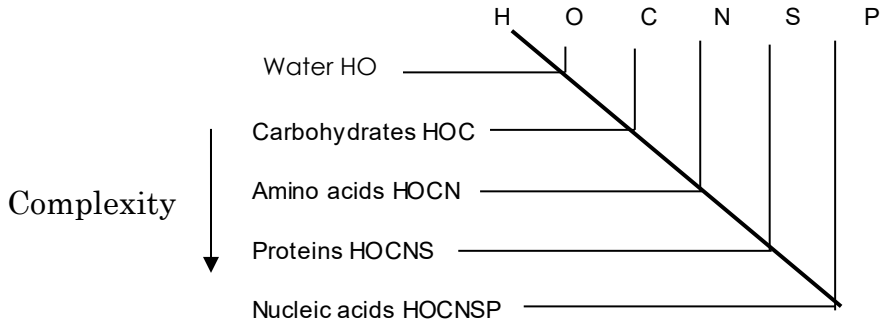


*Figure 2.2 This figure illustrates the hierarchical nature of increasingly complex molecules essential to life (Altman, xxxx).*

#### 2. Carbohydrates (HOC)

Six, or multiples of six, carbons
H and O in proportion of two to one as in water
Energy rich and most important source of organic energy
Hexose sugars
Monosaccharides - glucose (used directly by cells)
Disaccharides - sucrose
Polysaccharides - starch glycogen

#### 3. Proteins (HOCNS)

Most important of all organic compounds
No organism lacks proteins
Each species has it own
Proteins built from about 20 amino acids.

All amino acids contain an amino group (NH2) (a base which acquires hydrogen ions) and a carboxyl group (-COOH) (which is acidic and can make available protons). Amino acids can, therefore, behave as an acid or a base depending on the solution they are in.

#### 4. Nucleic Acids (HOCNSP)

##### a. RNA

In nucleolus and cytoplasm and is concerned with everyday synthesis of proteins.

##### b. DNA

Carrier of the genetic code
Double helix with sequences of:
adenine
guanine
cytosine
uracil
thymine

### C. Mechanisms Underlying Molecular Interaction

Two principles could account for many basic cellular processes such as genetic replication and enzymatic activity.

1. lock and key machinery
2. difference in the stability of different structures
3. some structures having emergent properties that accomplish things

For example:

#### 1. Assembly

Suppose some shape "1" matches a second shape "2" as a round peg in a round hole. Other shapes "3" and "4" are like a square peg in a square hole.

Suppose that a stable string of differently shaped holes

1—3—5—7

had some emergent properties, for example, the digestion of cellulose.

Reproduction could occur as follows: the above string (1—3—5—7) could passively pick up its individual complementary pegs as shown below simply by way of the chemical structure of each unit as round pegs in round holes.

1—3—5—7
2 4 6 8

The complementary pegs could in turn bind together because the 1-3-5-7 chain holds the 2, 4, 6, and 8 elements together in a position that makes their interconnection happen.

1—3—5—7
2—4—6—8

If the existence of the 2—4—6—8 bonds overwhelmed the 1—2, 3—4, 5—6, and 7—8 bonds, then the 2—4—6—8 compound would be ejected from the template. There would then be a 2—4—6—8 chain floating around which could in turn collect its own "holes" which would reproduce the 1—3—5—7 molecule that would then be ejected and would then digest cellulose. This is a primitive form of reproduction.

1—3—5—7
2—4—6—8

### 2. Disassembly

This is basically the reverse of assembly.

1—3—5—7 + 2—4—6—8

In this case, the 1-3-5-7 chain picks up the 2-4-6-8 chain.

1—3—5—7
2—4—6—8

The 1-2, 3-4, 5-6, 7-8 bonds overwhelm the 2-4-6-8 bonds.

1—3—5—7
2 4 6 8

This in turn leads to the ejection of the 2, 4, 6, and 8 as individual entities.

1—3—5—7 + 2 4 6 8

This process breaks down complex structures into their component parts.

# IV. Cellular Adaptation

### A. The Evolution of Complex Functional Relationships Through Recursive Hierarchical Control Mechanisms

The overwhelming majority of people accept that cellular activity is a materialistic, albeit very complex process. There are however a few pre-Galileans and pre-Cartesians out there that believe there are minds in the liver and

pancreas and possibly even in an amoeba or planaria. The intent of this section is to provide a simple hierarchical framework with which to see materialist causation in the organic foundations of behavior.

This section is an attempt to demystify the cellular machinery underlying behavioral adaptation in less than 5 pages (i.e., all the facts, processes, explanatory logic and proof generated over the last 2-3 thousand years by biologists). If you need more than the subsequent very quick, shallow review presented in this chapter to see the materialistic determinism and hierarchical organization of the biological machinery underlying behavior or if you want the up-to-date details of the knowledge base of Biology, consider it essential that you read supplemental material available in the library or on the internet.

In simple terms, at the bottom, the physiology of organisms is nothing more than 1) inevitable materialistic chemical reactions with no invisible magical cause, and 2) the recursive hierarchical organization and control of those simple inevitable materialistic chemical reactions without any emergent invisible magical cause whatsoever. All individual and hierarchical or holistic cellular processes are "stupid." In principle, just like kinetic art. The incredible complexity of kinetic art must come from inevitable materialistic hierarchical processes. It is not even alive and after all, you can't get much more "stupid" than something that isn't even alive.

It is important to understand and believe that even the most complex human behavior is at the bottom only simple inevitable purely materialistic cellular, chemical, and quantal processes.

If you believe that it is essential to understand the details of biology in order to understand the details of behavior, keep in mind that first you will have to understand the details of behavior otherwise you will fail to understand what provides the input to the biological adaptation and will fail to understand the function of the biological adaptation. Without understanding the functional relationships of behavior, Biology becomes disembodied with neither a beginning nor an end.

If you believe that you cannot understand behavior until you understand the biology that is below that behavior and which in some sense makes that higher-level work, then you, by your own logic, will have to study quantal physics until you have it explained, then chemistry until that is understood, then biology until no questions remain in that field, and then finally study psychology (if you live so long). If you claim you must understand what underlines psychology but need not understand what underlies Biology, then you are being either arbitrary or a hypocrite.

### B. Evolution of Vegetative Cellular Adaptation

The processes pertaining to an organism can be classified as vegetative or animative. Vegetative processes are the more fundamental and are shared by all organisms - plant or animal. They are passive inevitable materialistic chemical processes. In simplistic terms, it would be all those activities that maintain life in

a plant or a comatose animal.

The more fundamental and ancient integration system is a humoral (or chemical) one. It is hormonal communication, integration, and adjustment. There is no nervous system in plants yet they show integration and adjustment. The CNS is a very recent evolutionary development and integration was shown well before its emergence.

Hormones are chemically very heterogeneous and plant and animal hormones are very different. Most animal hormones are not species specific though.

They are effective in extremely low concentrations (e.g., 1 in 5 billion). Hormone concentrations are very important; at one concentration one effect can occur, at another concentration the opposite effect can occur. Hormones production in many cases is under the control of their target so that a negative feedback system exists.

### 1. Vegetative or Hormonal Integration and Adjustment in Plants

Much of what animals achieve by swift animative neuromuscular action is attained in plants by slower structural adaptations under chemical control.

An early investigator in plant adaptation was Darwin. He noted that the tip of canary grass tipped toward the light because the tip was sensitive to the light, but that the extra growth occurred well below the tip. Darwin showed this by covering the tip but not where the growth took place. He showed that the effect was chemical in nature by cutting the plant and inserting a gel block. The chemical passed through the gel. Any neural structures would have been severed. These chemicals have been named auxins.

Darwin noted that plants were remarkably adaptive. They moved toward the light. He noted that the growing tip always moved as it grew. It tended to rotate. The upward growth of the plant is directed (negative geotropism). The turning of the growing tip is undirected in its rotation but tends toward the light. When the tip encounters a vertical obstacle, it tends to twine around it together with the upward growth. The plant is lifted to a higher location. The adaptiveness of a large class of plants can be explained by negative geotropism, circumnutation and positive phototropism.

Plant movement is usually labeled in terms of the stimulus causing it such as phototropism or geotropism and positive or negative depending on whether it's towards or away from the stimulus.

Most of the auxin caused adjustments in plants are accomplished by growth processes. If one side grows more, then the plant bends the other way. These adjustments are slow.

### 2. Vegetative or Hormonal Integration and Adjustment in Animals

In animals, hormones alter the rate of some target activity in target cells. Every cell in the body is exposed to a hormone release. This control system is ideal when many systems of the body must be coordinated, such as: if predator, then

increase heart rate, deepen respiration, dilate blood vessels in muscles, contract blood vessels in skin, release sugar from liver, etc. However, in some cases only a few parts of the body may react to the exposure. The effect of a hormone is prolonged whereas the effect of nervous activity is very short. The chemical structure of animal hormones varies, the source varies, the target varies, and the pervasiveness varies. There are probably many unidentified hormones remaining.

#### a. Hormonal Coordination of Integrative Processes in Animals

Pituitary

Adrenohypophysis

growth hormone – affects skeletal growth
thyrotrophic - affects the thyroid
corticotrophic - affects the adrenal cortex

Neurohypophysis

Neural origin - nerve cell secretions transmitting neural influences to glandular structure controlling vegetative functions

Hawk moths move up or down in relation to gravity depending on their age, the behavior is governed by the amount of juvenile hormone.

##### i. Pheromones

These are chemical substances which function like hormones except their transmission is outside the body.

Sexual attractants
Chemical alarms
Chemical trails
Social control (as in honeybees)

The queen produces a substance that inhibits the development of ovaries in the female workers. When the hive gets too large, some females don't get the substance. Ovaries develop in other bees and large queen cells are built and new queens are produced.

### 3. Conceptual Overview: Trends in the Elaboration of Hormonal Integration in Animals

The first hormones seem to have been the simple products of nerve cells. The secretion was used locally. This type of process can be seen in the flatworms. Storage of the secretion of nerve cells then emerged. This can be seen in annelids. Later there was the emergence of non-nervous endocrine glands in various regions of the body under the control of neurosecretory cells in the CNS.

### C. Evolution of Animative Cellular Adaptation

There are two ways an organism can satisfy their metabolic needs:

1. synthesizing the organic compounds from inorganic substances
2. acquiring already synthesized organic compounds and transforming them into their own species specific compounds

This difference may have led to the difference between plants and animals. Animals must search for and capture food and avoid predation whereas plants are relatively passive. Most vegetative processes are dependent on humoral events, animative processes on the other hand are dependent on biomechanical events. Animative activities are superimposed on top of vegetative processes and are for the satisfaction of vegetative needs through interaction with the environment and are the biomechanical, neuromuscular activities of animals.

Differentiated animative action has three aspects: 1) information gathering, 2) coordination and 3) execution of action.

#### 1. Information Gathering

This includes any sensory apparatus such as eyes, ears, and nose.

#### 2. Execution of Action

This includes any action mechanism such as legs or tail.

Amoebas are capable of not only moving around but also exhibiting organized behavior. They have discriminative as well as adjustive capacities. Amoebas manifest rudimentary sensory capacities, when they move toward or away from a source of stimulation even though differentiated sensory mechanisms are not present.

Paramecia show an avoidance reaction to a variety of stimuli. They stop moving and reverses direction. They do this by reversing the beat of their cilia, then turning slightly, then moving forward again. The turn is random because the paramecium has no distance receptors to determine the vector to the stimulus. If the anterior part of a paramecium is stimulated mechanically, the permeability of the cell membrane to calcium ion increases, the cilia reverse their beat due to the resulting changes in the ion balance and electrical charge across the cell membrane. Stimulation of the posterior part of the cell increases potassium permeability and the cilia beat more rapidly.

In metazoans such as sponges, nerve cells are absent. The contractile cells in the osculum of sponges respond directly to external stimuli without mediation of nerves.

#### 3. Coordination

This includes any neuronal system that coordinates action.

The perspective that the nervous system is composed of discrete cells with fibrous processes that have synapses is known as neuron theory.

The simplest "input/output" neural unit that can control behavior contains two neurons. It is called a monosynaptic reflex arc (e.g., stretch reflex). The prototypical example is the knee tap leg jerk reflex.

The next most complex neural unit is a three-neuron arc such as in a simple withdrawal reflex. Obviously, a very large number of neurons could be involved in some behaviors.

From an internalistic perspective, all of the behavior of an organism is either under hormonal control or the result of neurons being triggered by one or more other neurons. All behaviors or decisions are simple hormonal or neuronal activities. There is no "free will."

### 4. Conceptual Overview: Trends in the Elaboration of Coordination in Animals: The Nervous System

The basic characteristic of a centralized nervous system is the segregation of centrally located nerve centers or ganglia and their communication lines, where interaction among and coordination between various body parts may take place.

#### a. Condensation / Development of Ganglia

Cords arose by condensation of the network of plexuses of bipolar and multipolar neurons. Cell bodies become localized into ganglia so that cords consist mainly of fiber. Many neural elements become concentrated into the ganglia and cords of the CNS.

#### b. Cephalization

A head is developed at the anterior end of the bilateral animal. Neural concentration occurs there. The trend across evolution is obviously toward cephalic dominance expressed structurally as increased relative size and differentiation of the cephalic ganglion. This progressive process is referred to as cephalization.

#### c. Differentiation

The brain further develops so that a separation of transmission function (nerve tracks) and integration (ganglia and brain) function occurs.

#### d. Development of Giant Nerve Fibers

High-speed transmission emerges with giant neurons associated with behaviors such as escape.

### e. Grouping and Specialization of Function

Single cell organisms evolve subcomponents that carryout necessary functions. Single cell organisms can fail to separate when they reproduce and can become clusters. The individual cells in the cluster can each then specialize and carryout those same functions more efficiently and effectively than a single cell doing all the functions by itself.

Multicellular clusters can also develop clusters when they reproduce and fail to separate. Rather than a cluster of individual cells this would be a cluster of multicellular clusters. It would be rather like an apartment building being the same floorplan reproduced over and over in a stack 30 stories tall. Different "floors" can then each develop specialization of function and could more efficiently and effectively adapt. Additionally, individual "floors" could interact and pass information.

For example, in amphioxus, an exemplar of a basic body plan, the elongated body has many separate segments, clusters, or "floors" that can contract alternately on the right and left side. It has a notochord or an inter segment communication line which gives off sensory and motor nerves laterally to the right and left in each segment. This amphioxus notochord is present in all vertebrates during early embryological development.

Different "floors" can further specialize independently and a head could emerge (i.e., the "executive" floor). The lamprey, an exemplar of this more complex body plan, it has a definite head, and specialized sense organs in the anterior region. The CNS of the lamprey represents the common core of the vertebrate nervous system.

### f. Recursive Hierarchical Control of Control Systems

The hierarchical social organization of humans provides a good metaphor for the hierarchical organization of cells. As there are individuals, families, towns, counties, states, nations, and unions, each receiving integration control from the next higher stage, and in turn directing the next lower levels of organization so too are the cellular systems of an individual organism organized. When you think about it, the president of the United States deals with about a dozen people just as the governors deal with about a dozen people and just as the mayor of a small-town deals with about a dozen people. The only difference is that the White House staff in turn deal with a dozen people each where the small-town mayor deals with the final stage of the actual workers.

# CHAPTER 3

# Causal / Contextual Processes More Molar Than Organismic Adaptation

## I. Introduction

## II. Group Adaptation

## III. Systematic Adaptation

# CHAPTER 3

# Causal / Contextual Processes More Molar Than Organismic Adaptation

## I. Introduction

This chapter provides a very short simplistic overview of the class of functional relationships above organismic adaptation in molarity. They are depicted as the two gray columns in Figure 3.1. This chapter should give you: 1) unshakeable confidence that there is nothing but materialistic causation at these levels of molarity, and 2) an understanding of what functional relationships are neither a target of research in EAB nor a source of explanations.

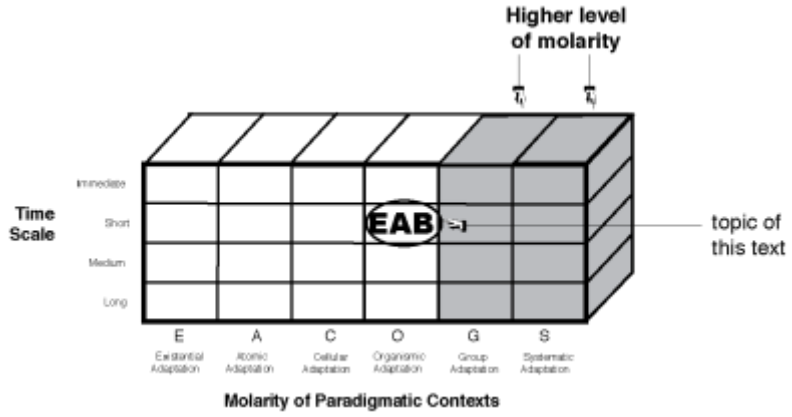


*Figure 3.1 Figure showing the relationship to EAB of levels of adaptation higher than organismic adaptation (group and systematic adaptation) (highlighted in gray).*

Every action of every group and system is caused by some natural process in the natural world. Each is a simple inevitable reaction of the environment to changes in other aspects of the environment. There is no need for mental processes, space alien intervention, or magical causation.

# II. Group Adaptation

The causal functional relationships underlying group adaptation should not be confused with the average behavior of N specific instances of organismic adaptations where each individual organism was exposed to its own individual contingency that was explicitly dependent on the behavior of that specific individual. For example, the overall result of a group of 25 children with 25 individual piano teachers is not an example of group adaptation, rather it is the average of 25 organismic adaptations to the same contingency. Group adaptation refers to an independent variable that provides some common exposure to all individuals or some contingency that all individuals in the group could come in contact with (or not); and a dependent variable that is determined by the overall or mean behavior of all individuals.

For example, if 100 people are given some questionnaire, then exposed to a movie, and then given a follow-up questionnaire; it is the change in the mean score on the questionnaire that is the dependent variable and the exposure of the group as whole to the movie is the independent variable. How the movie functioned with respect to any specific individual's reinforcement history is confounded and is not separately considered.

Excellent examples of this level of analysis is provided by monitoring the frequency of specific tweets or Google searches in a population as a function of events the population was exposed to, such as current events.

# III. Systematic Adaptation

The systematic level of adaptation provides for a closed system cause (all the causal factors are within the system to be explained).

# CHAPTER 4

# Immediate Time Scale Organismic Adaptation: The Expression of Behavior to Stimuli or "Reactions"

**I. Introduction to Immediate Time Scale Adaptation or "Reactions"**

**II. Formal Defining Properties of Immediate Time Scale Adaptation**

**III. Trial by Trial Example of Immediate Time Scale Adaptation**

**IV. Characteristics of Immediate Time Scale Adaptation**

**V. The Assessment of Immediate Time Scale Adaptation**

A. Time scale of the origin of the stimulus response relationship which instantiates the reaction
   1. Short
   2. Medium
   3. Long

B. Typical IV in immediate time scale adaptation

C. Typical DV in immediate time scale adaptation

**VI. Explanatory Framework for Immediate Time Scale Adaptation**

A. Externalistic (behavior analytic or "ecological")

B. Internalistic (cognitive)

## VII. General Classes of Reactions

A. Conceptual precursor: only an arbitrary subset of all possible classes of reactions are presented in this section
B. Conceptual precursor: the terminology is only descriptive rather than explanatory
C. Conceptual Precursor: Graphical conventions
D. Changes in reaction strength: stimulus change effects
E. Changes in reaction strength: stimulus intensity effects
    1. Threshold
    2. Irradiation
    3. Latency
F. Changes in reaction strength: successive presentation effects
    1. Temporal summation
    2. Refractory period
    3. Fatigue
    4. Sensory adaptation
    5. Habituation
    6. Potentiation
G. Changes in reaction strength: second stimulus effects
    1. Successive induction
    2. Reciprocal inhibition
    3. Spatial summation
    4. Cooperation
    5. Sensitization
H. Changes in reaction strength: prior procedure effects
    1. Pseudo-conditioning
    2. Dishabituation
    3. Disinhibition
    4. Spontaneous recovery

# CHAPTER 4

# Immediate Time Scale Organismic Adaptation: The Expression of Behavior to Stimuli or "Reactions"

## I. Introduction to Immediate Time Scale Adaptation or "Reactions'

This chapter provides a very short simplistic overview of the class of functional relationships labeled immediate time scale adaptation. It is depicted as the cell above short time scale organismic adaptation in Figure 4.1. This chapter should give you: 1) unshakeable confidence that there is nothing but materialistic causation in immediate time scale adaptation and 2) an understanding of what functional relationships are neither a target of research in EAB nor a source of explanation.

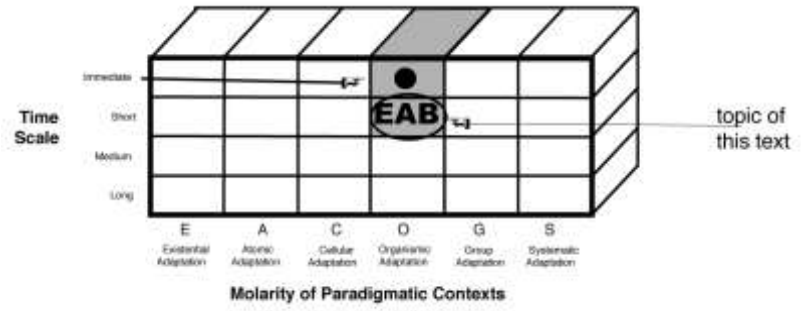


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*Figure 4.1 Figure showing the relationship to EAB of the adaptation of levels of molarity below organismic adaptation (i.e., existential, atomic, and cellular adaptation) (highlighted in gray).*

A prototypical "reaction" is a pigeon pecking a key when it turns green.

The topic covered in this chapter (reactions to stimuli) is simply the expression of a behavior, and is not the primary focus of the experimental analysis of behavior because it is simply an organism's reaction to a stimulus rather than the acquisition or emergence of a semi-permanent learned behavior that reverses over a short time with a contrary contingency.

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

pigeon pecking or a person saying "I see the light." typically It is a behavior change as soon as the stimulus changes, and can be said to be caused by the stimulus change.

# II. Formal Defining Properties of Immediate Time Scale Adaptation

The time scale across which a measure of behavior emerges defines its time scale of adaptation. Figure 4.2 below depicts immediate time scale adaptation. it is a re-presentation of Figure 1.4.

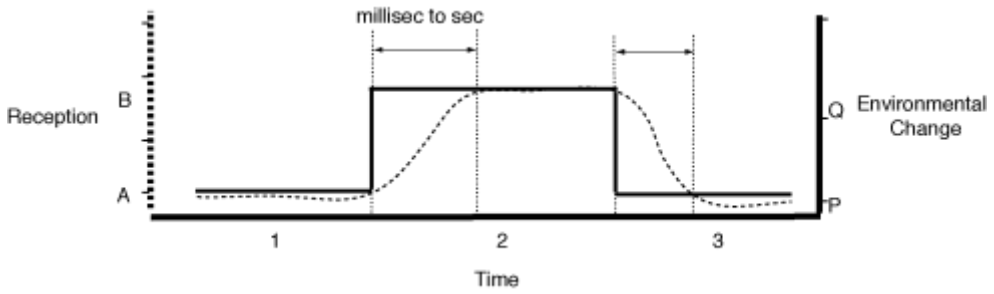


*Figure 4.2 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag in the milliseconds to seconds range the dependent 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-to-seconds range of the dependent variable returning to State A and again coming into equilibrium with the independent variable at Time 3.*

# III. Trial by Trial Example of Immediate Time Scale Adaptation

Figure 4.3 depicts the procedures and results from two subjects across a three phase experiment. In the first phase, each animal is subjected to 12 occurrences of a US. Note that the US is not paired with anything. The behavior during the trial increases in magnitude across the 12 trials in both animals. In Phase 2, one animal experiences only the passage of time, while the second animal receives a trials only procedure with no US. No behavior occurs in either animal during with these two procedures. Phase 3 is a repeat of the procedures in Phase 1. As can be seen, the behavior is initially zero, but increases across the 12 trials in both

animals. The behavior of the animals had spontaneously reversed to its base rate in both the "time only" and the "no US" procedure.

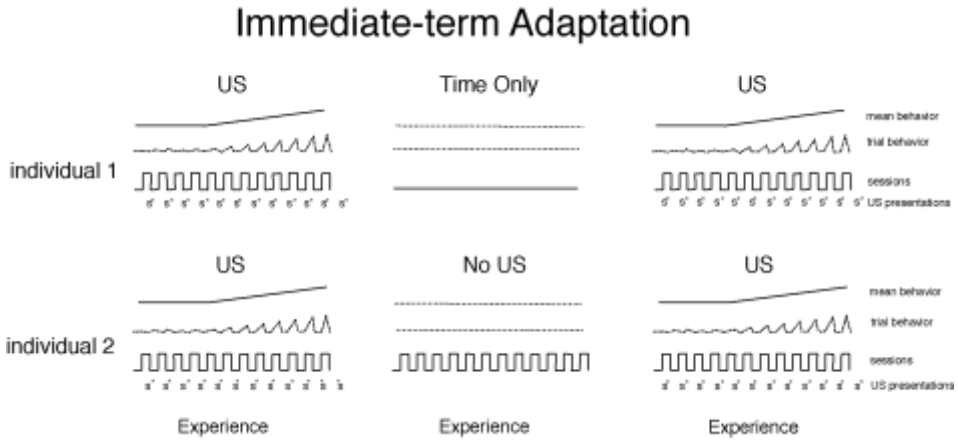


*Figure 4.3 The figure presents procedures and data from two individuals exposed to procedures in order to illustrate immediate-term adaptation. In the left column, both individuals show a behavior change with experience. The S*s along the bottom of each frame represent presentations of a US in isolation. The square wave designates sessions. The sawtooth line above the square wave depicts the amplitude of the reaction to the US or dependent variable. The behavior can be seen to grow stronger across sessions. The top line in each frame of the left column represents the average amplitude of the dependent variable and documents the increase in strength exhibited by the dependent variable. The center column shows that Individual 1 then experiences only the passage of time while Individual 2 experiences sessions with no US. No behavior occurs in either group. Finally, the right column illustrates that when subsequently given sessions with a US again, performance is the same as in the initial exposure for both individuals (which was illustrated in the left column). There was no retention of an effect of the initial training in either group.*

Note in Figure 4.3 that the behavior of both animals in each of the blocks of training starts from scratch (the magnitude of the trial behavior at the beginning of Phase 1 and at the beginning of Phase 3) because there is no semi-permanent carryover of the effects of training. This is worth reiterating. This adaptation does not show a semi-permanent change in behavior.

# IV. Characteristics of Immediate Time Scale Adaptation

(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 and shows no semipermanence

(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.

# V. The Assessment of Immediate Time Scale Adaptation

Research on this time scale of adaptation is focused on the simple expression of a behavior or a reaction to a stimulus when that stimulus changes in some way. For example, from darkness to an illuminated light or when that stimulus changes from in a 555 nm green light to a 560 nm green light.(figure 4.4)

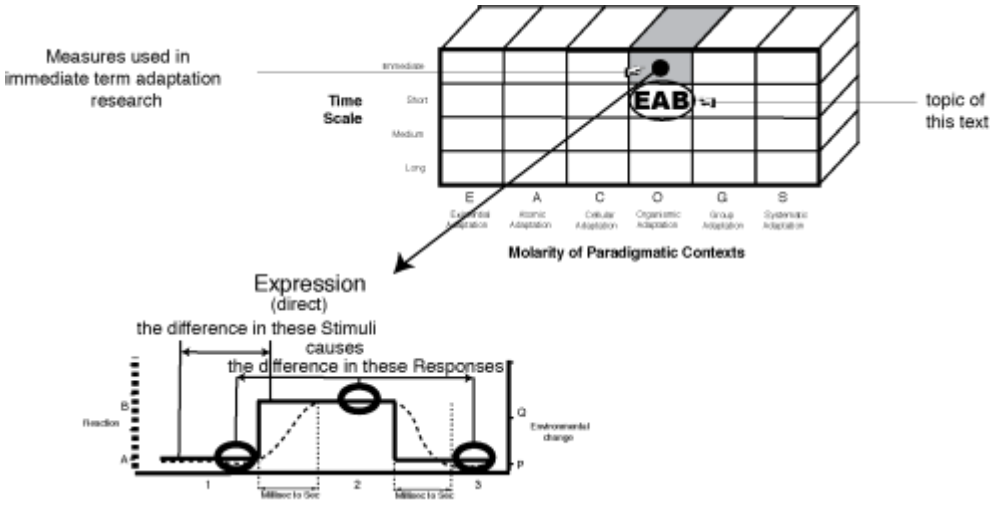


*Figure 4.4 The figure depicts immediate-term organismic adaptation that is the time scale covered in the present chapter (highlighted in gray) with respect to short time scale adaptation or EAB. Note that the procedure to assess the expression of a reaction need only be the single occurrence of a single stimulus change and the organism's reaction to that stimulus change. The difference from the stimulus being absent to the stimulus being present is seen as causing the difference in the behaviors (i.e., the reaction).*

The data pertinent to immediate time scale adaptation is the static details of reactions to the stimulus (structural information), For example, if an eye blinks when a light is turned on, then the focus is on how characteristics of the light such as its hue or intensity affects details of the expression of the complete reaction or its latency. In each case, the hysteresis is in the milliseconds-to-seconds range.

Simple reactions are also sensitive to variations in the context of the controlling stimulus as well as variations in the stimulus itself. The context change may be as simple as the occurrence of other stimuli, or it could be the

history of experience with that particular stimulus, or even the state of the organisms such as a history of food deprivation. As a result, immediate-term behavioral adaptation includes behavior changes to repeated occurrences of the same stimulus (ear twitches to gunshots for example) that show onset hysteresis (it is slowly acquired). However, those changes disappear with nothing more than the passage of time (i.e., they spontaneously reverse). They are not semi-permanent. Habituation, sensitization, and potentiation are not short time scale behavioral adaptations; rather they are immediate-term adaptations

In a computer metaphor, the loss of the adaptation is like the loss of data in RAM when the power is turned off These adaptations are said to be non-associative because behavior is not semi-permanently coming under the control of, or "being connected to", any specific stimulus.

What made the organism behave in some particular way to some 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.

It is especially important to point out that confounding changes across any other timescale of adaptation could have significant effects on simple immediate-term reactions. For example, changing the reinforcement history for detecting a stimulus would have an effect. and that that threshold change would show short time scale hysteresis (a learned effect).

### A. Time Scale of the Origin of the Stimulus Response Relationship Which Instantiates the Reaction

Immediate-term adaptation pertains solely to the expression of its functional relationship. How that particular response to that particular stimulus emerged is a different issue. The specific response occurring to that specific stimulus had been established across the short, medium, or long-term time scale.

#### 1. Short

Exactly which behavior occurs when the stimulus occurs can be via short time scale adaptation. For example, saying "I see the light" when a light is illuminated after having been told what to do when the light comes on, or a pigeon pecking the key when it is green after having been reinforced for pecking a green key.

#### 2. Medium

The behavior to the stimulus can be the result of many overlapping contingencies that condition "Dispositions" or enduring functional relationships of behaving in some particular way

### 3. Long

The behavior to the stimulus can be the result of functional relationships established by evolution such as reflexes, taxes, kinesis, and modal patterns. For example, a hand withdrawing when stuck with a pin, or a goose flying to Patagonia when the light cycle shortens.

### B. Typical IV in Immediate Time Scale Adaptation

Most often, immediate-term 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). if the eliciting or evoking properties of a green light are under investigation while holding the other time scale histories constant, then it is immediate-term research.

However, if properties of the reinforcement history are varied while holding the properties of the light constant, then it is short time scale research. If properties of the light are held constant and the reinforcement history is held constant but the reproductive success of different behaviors to the light are increased or decreased, then the research is long-term research. If all three dimensions vary simultaneously, then the results cannot be attributed to processes operating at one time scale or the other without further clarifying research

### C. Typical DV in Immediate Time Scale Adaptation

The adaptation of an individual organism at this time scale is not typically a topic of interest for behavior analysis even though it could be. The change in behavior 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.

# VI. Explanatory Framework for Immediate Time Scale Adaptation

### A. Externalistic ("Behavior Analytic" or "Ecological")

In its simplest form, the answer to the question "why did the animal respond?" is given as "because the stimulus occurred."

A more comprehensive approach could specify the external factors that vary the objectively measurable reaction to the stimuli (i.e., functional analysis). This "outputs as a function of inputs" approach is illustrated in Figure 4.5.

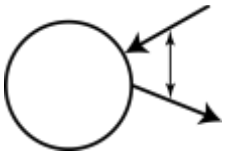

*Figure 4.5 The occurrence of stimuli or the relationship among stimuli can be shown to be necessary or sufficient to cause the behavior of the organism and are therefore the data elements of exclusive interest in immediate-term adaptation.*

This functional analysis approach would include characteristics of the stimulus as was illustrated by the anecdote about the cause of egg retrieval in geese. Additional examples would be the effects of stimulus intensity, characteristics of the organisms (e.g., deprivation), characteristics of the response itself (This approach to conceptualizing reactions to stimuli as opposed to the mind-receiving stimulation was pioneered by James Gibson and is labeled Gibsonian Psychology or Ecological Psychology.

A causal explanation based entirely on the functional properties of an entity at its defining level of molarity is considered complete regardless of that level. Each is a simple inevitable reaction of the environment to changes in other aspects of the environment. There is no need for mental processes, space alien intervention, or magical causation.

Research into how that blink to a light came about, whether via a reinforcement history, or evolution, for example, would change the label for the research to the appropriate other time scale.

### B. Internalistic (Cognitive)

This traditional approach creates an internal entity that "sees" some internal representation of the stimulus projected into the brain somehow and then "reports" an interpretation of that stimulus to the cognitive processor which in turn makes the mouth say: "I see the stimulus" or makes the body react to the stimulus by pushing a button. The cognitive processing center would be given various resources and liabilities that would sum to whatever was necessary to mimic the actual obtained functional relationships. The productivity of this approach is not universally accepted.

## VII. General Classes of Reactions

### A. Conceptual Precursor: Only an Arbitrary Subset of All Possible Classes of Reactions Are Presented in This Section

The present list of functional relationships is a subset of the extremely wide variety of reactions to stimuli resulting from all possible short, medium, and long-term adaptations and their interactions. The present list of the functional

properties of reactions is primarily based on reflex responses because those reactions are the most systematically categorized. Often these characterizations are used to describe the properties of reactions established across other time scales that have similar functional properties.

### B. Conceptual Precursor: The Terminology is Only Descriptive Rather Than Explanatory

Note that the following categories of reactions are not explanatory but rather are descriptive. It is important to avoid slipping into the erroneous belief that the label is the cause of the functional relationship. For example, the loss of reaction strength with repeated elicitation is labeled fatigue - **it is not caused by fatigue.**

### C. Conceptual Precursor: Graphical Conventions

Test A, Test B, .... can occur in any order
Test 1, Test 2, ... occur in order.
Exp A Exp B ... indicate different groups.
Relative stimulus and response strength is indicated by font size

time
----------> indicates a continuous series of presentations

### D. Changes in Reaction Strength: Stimulus Change Effects

It should come as no surprise that changes in a stimulus from red to green or from on to off could change the behavior to "the" stimulus. For example, if someone is told to say when they see a green light, they will say "I see the green light" when it is illuminated or when a red light changes to green.

Seen from the opposite perspective, any aspect in the natural world that reliably controls a change in behavior could be defined as a stimulus change, while those "stimulus changes" that don't result in a behavior change could be defined as the absence of a "stimulus change." For example, adding one candle to a thousand candles may be a change according to some measure but not a change as far as the behavior of the subject is concerned.

### E. Changes in Reaction Strength: Stimulus Intensity Effects

#### 1. Threshold

A reaction will occur to a stimulus of sufficient intensity (Figure 4.6). Below that intensity a reaction will not occur. The defining property of this phenomenon is that the intensity of the controlling stimulus alters the probability of the reaction occurring. The proportion of presentations that a particular stimulus intensity is effective increases as a sigmoid function of the energy level of the stimulus.

Note that the proportion of detections is altered by the subject's history with respect to the cost of false alarms and misses with respect to the gain associated with correct detections and correct rejections. However, that effect is a short time scale adaptation not a simple immediate-term adaptation.

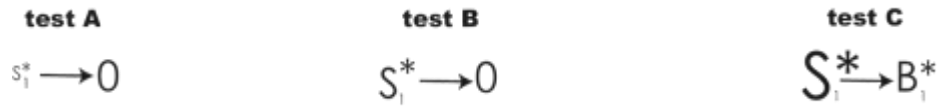


*Figure 4.6 Figure illustrating that as the stimulus increases in strength, it eventually controls a response.*

### 2. Irradiation

More intense stimuli control reactions in more response systems (Figure 4.7).

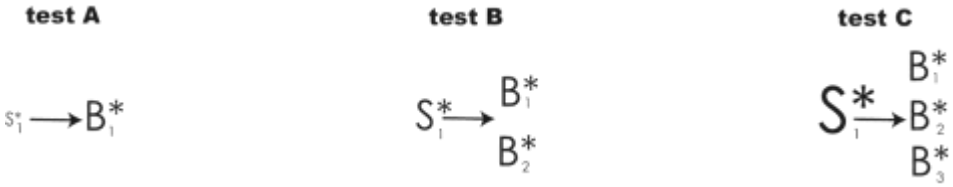


*Figure 4.7 Figure illustrating that as the stimulus increases in strength, it may eventually control responses from more response systems.*

### 3. Latency

More intense stimuli produce a reaction with a shorter delay from the stimulus onset (Figure 4.8).

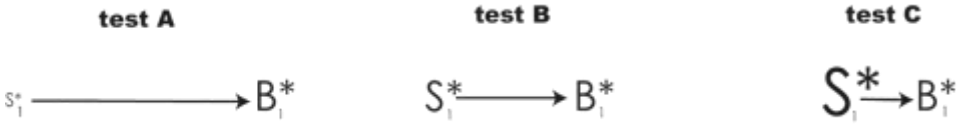


*Figure 4.8 Figure illustrating that as the stimulus increases in strength, the reaction it controls occurs with a shorter delay.*

## F. Changes in Reaction Strength: Successive Presentation Effects

### 1. Temporal Summation

Two occurrences of a sub-threshold stimulus if presented together in close temporal proximity can cause a reaction to occur (Figure 4.9).

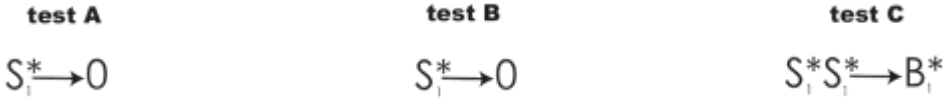

*Figure 4.9 Figure illustrating that a stimulus may fail to control a response but when presented in quick succession may control a response.*

### 2. Refractory Period

After once elicited, the threshold necessary for a reaction may increase for a short time (Figure 4.10). Alternatively stated, it takes more to control a reaction the second time if the attempts are made in quick succession. This effect is the inverse of temporal summation.

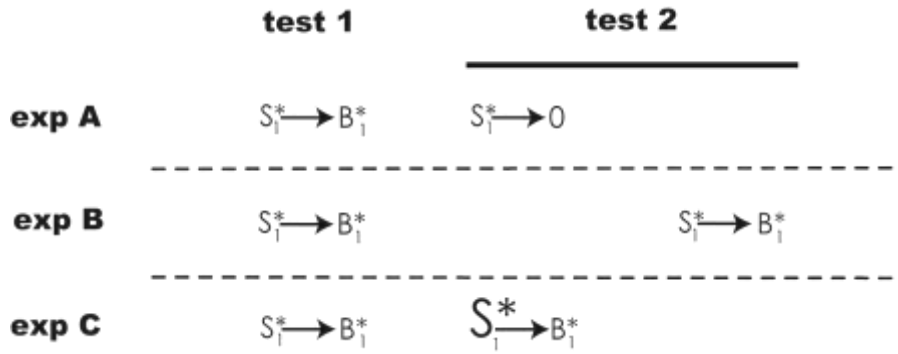


*Figure 4.10 Figure illustrating that a stimulus that controls a response may fail to control a response when re-presented immediately. A more intense version of the stimulus if presented in close succession may still control a response.*

### 3. Fatigue

Fatigue is a reduction in the reaction to a stimulus thought to be the result of "overuse" of the motor system (Figure 4.11).

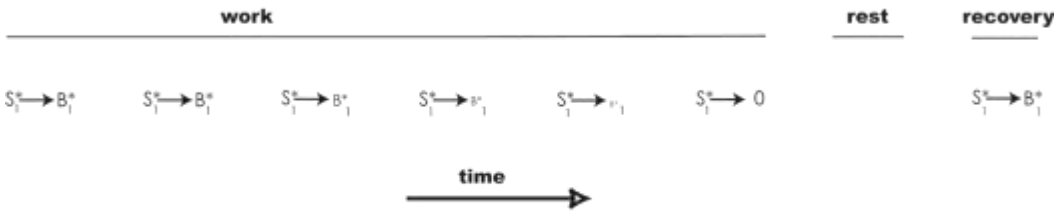


*Figure 4.11 Figure illustrating that the repetitive presentation of a stimulus may result in a weaker response and may eventually fail to control a response until a rest period occurs.*

### 4. Sensory Adaptation

Sensory adaptation is a reduction in the reaction to a stimulus thought to be the result of “overuse” of the sensory system (Figure 4.12).

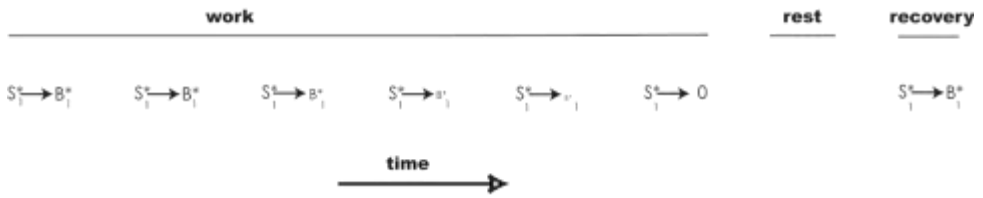


*Figure 4.12 Figure illustrating that the repetitive presentation of a stimulus may result in a weaker response and may eventually fail to control a response until a rest period occurs.*

### 5. Habituation

Successive presentations of the same stimulus can diminish the effectiveness of reflex elicitation (Figure 4.13). Habituation is thought to be the diminution of a reflexive response as the result of the experience of repeated elicitations. For example, if someone were giving a lecture and said your name every minute or so, you would initially look up each time, but would eventually cease looking up each time. This effect is thought to be the result of repeated elicitations by a specific stimulus.

Several potential explanations can be ruled out:

1) Not sensory adaptation because only one of many responses to the stimulus may drop out. For example, you could continue to take notes of the lecture and even keep track of the number of times your name was mentioned. You would not be "blind" to the stimulus.
2) Not response fatigue because a different stimulus will elicit the same reaction. A different person could say your name and you would respond by looking up. Your neck muscles still work.
3) Unlikely to be associative. The original functional relationship of looking up returns with nothing more than the passage of time. For example, after several weeks of not saying your name, if the lecturer said your name in the middle of the lecture, you would again look up. It is not semi-permanent. It is not a short time scale effect. Additionally, it is not due to the removal of a reinforcer for looking up nor is it due to the removal of an elicitor following a CS.

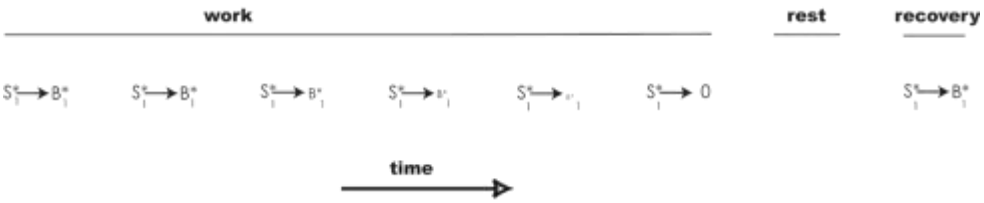


*Figure 4.13 Figure illustrating that the repetitive presentation of a stimulus may result in a weaker response and may eventually fail to control a response until a rest period occurs.*

### 6. Potentiation

Successive presentations of the same stimulus can increase the effectiveness of reflex elicitation (Figure 4.14). Potentiation is thought to be the increase of a

reflexive response as the result of the experience of repeated elicitations. The original strength of the functional relationship returns with no more than the passage of time. This effect is the inverse of habituation. This effect is thought to be the result of repeated elicitations. This functional relationship is labeled sensitization by some researchers.

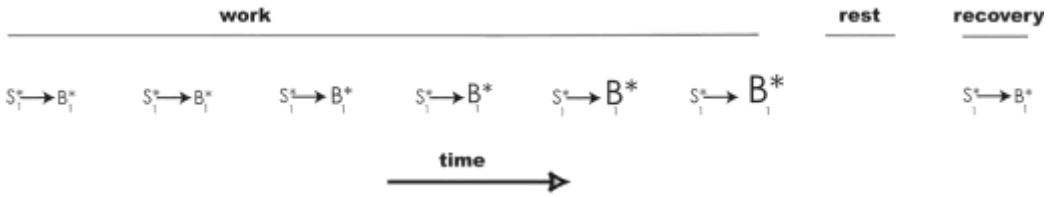


*Figure 4.14 The repetitive presentation of a stimulus may result in a stronger and stronger response until a rest period occurs.*

## G. Changes in Reaction Strength: Second Stimulus Effects

### 1. Successive Induction

A response can be facilitated by the prior activation of its opponent (Figure 4.15). For example, if CS+ and CS– randomly alternate, then successive induction is evidenced by the CS+ controlling an especially strong reaction immediately following the CS–, and the CS– controlling an especially weak reaction immediately following the CS+. This is a serial effect.

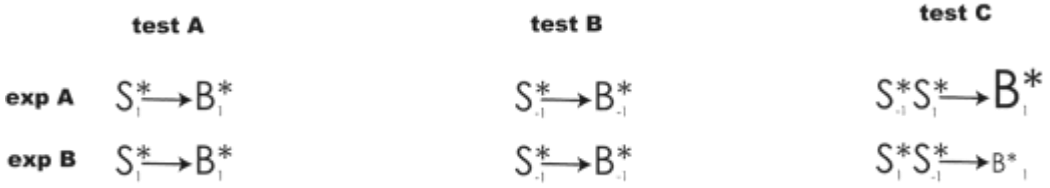


*Figure 4.15 When a stimulus controls a response and a second stimulus controls an opponent response, then when the two stimuli are presented in succession, the procedure may control a stronger response in the case of a positive stimulus, and a weaker response in the case of a negative stimulus.*

### 2. Reciprocal Inhibition

A response can be inhibited by the simultaneous activation of its opponent. For example, the activation of an extensor can be inhibited by the simultaneous activation of its flexor (Figure 4.16). This is a special case of the inverse reaction to that of successive induction. The special condition is that the stimuli are presented simultaneously rather than successively. This is a simultaneous effect.

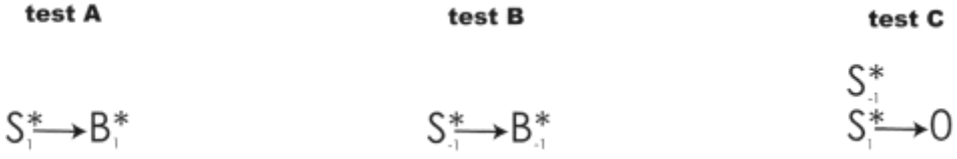

*Figure 4.16 When a stimulus controls a response and a second stimulus controls an opponent response, then when the two stimuli are presented simultaneously, the procedure may control no response.*

### 3. Spatial Summation

Spatial summation occurs when sub-threshold stimuli are presented in spatial proximity, when presented close together they will elicit the behavior (Figure 4.17). This is a spatial effect.

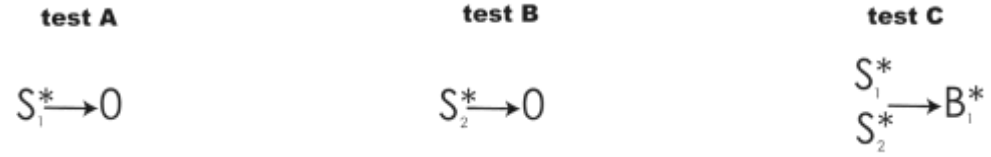


*Figure 4.17 When two sub-threshold stimuli are presented in spatial proximity, they may control a response.*

### 4. Cooperation

A sub-threshold stimulus for withdrawal and sub-threshold stimulus for scratch together are enough to lift the leg, even though they are two different systems (Figure 4.18). The relationship between the motor systems (i.e., similar output) is the defining property of this effect.

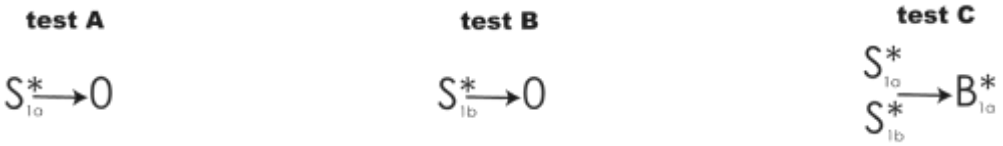


*Figure 4.18 When sub-threshold stimuli from different response systems are presented together, they may control a response.*

### 5. Sensitization

Sensitization occurs when a second stimulus presentation increases the effectiveness of some other specific stimulus in eliciting a response (Figure 4.19).

It appears that the sensitizing stimulus decreases the threshold for the target stimulus. For example, even though you might jump to a strong stimulus on the back of your neck, you normally do not react to a normal touch on the back of your neck. However, the sensitizing stimulus "seeing a cockroach" will likely cause a normal touch on the back of your neck to cause you to jump. Note the difference between the presumed baseline and the result following no treatment and a treatment. It is interesting to note that the sight of the cockroach will not change your taste or smell or even your reaction to your arm being squeezed.

Note that sensitization is sometimes used as a synonym of potentiation. This second usage of the label "sensitization" refers to an increase in reaction with additional presentations of the same stimulus. Strong stimuli are said to produce sensitization or an increase in the reaction with each stimulus presentation. Ideal usage would use the unambiguous term potentiation to refer to this latter effect.

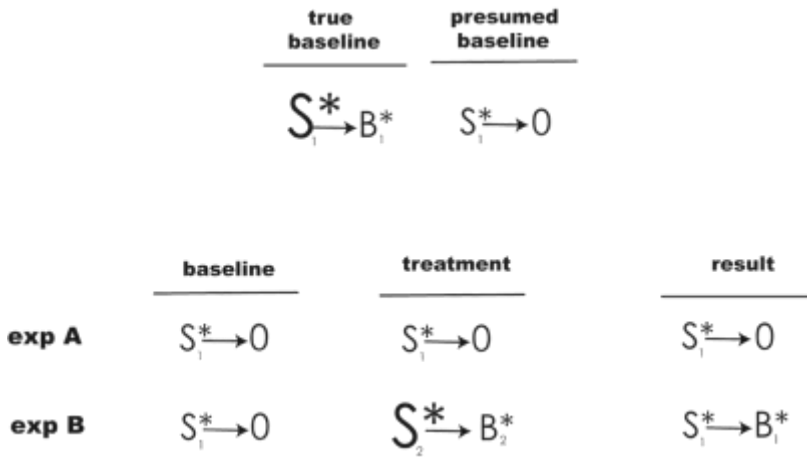


*Figure 4.19 If a sub-threshold level of a stimulus is used, then when a strong stimulus precedes the presentation of that sub-threshold stimulus, the sub-threshold stimulus may be able to control a response.*

### H. Changes in Reaction Strength: Prior Procedure Effects

The most notable example of this class is that following food deprivation, the reaction controlled by food presentation is eating, following a prior procedure of ad lib access to food, an animal will not eat food presented to it.

A related effect is that the deprivation/ad lib access procedure will also affect the ability of food presentation to function as a reinforcer. These latter (i.e., reinforcing) effects are essential to EAB. The deprivation procedure is said to establish food as a reinforcer while the ad lib access to food is said to abolish the ability of food presentation to function as a reinforcer. Establishing and abolishing operations will be covered in a subsequent section covering the effect "reinforcement" since "functioning as a reinforcer" is not strictly speaking a reaction.

#### 1. Pseudoconditioning

The concept of pseudoconditioning was established to differentiate some conditioning-like effects obtained in conditioning procedures from what was considered true conditioning.

The view was that in true conditioning a specific response was semi-permanently connected to a specific stimulus as the result of some internal associative process. For example, the association was between a specific cue (e.g., bell or CS) and the reinforcer (e.g., meat powder or US). The CR was thought to be "mentally" connected to the bell as the result of the bell being paired with meat powder because the animal had learned that the bell "signaled" meat powder.

The result of a training procedure is considered only pseudo-conditioning when a pairing of a specific neutral stimulus such as a bell and a strong stimulus such as a meat powder increases the effectiveness of any neutral stimulus in eliciting

a reaction (such as a light, a tone, or a touch on the leg) (Figure 4.20), rather than only the specific stimulus used in the training procedure.

This effect can occur even when the training stimulus cannot normally elicit the reaction even when at a stronger intensity (as depicted in the left portion of Figure 4.20). If the effect occurred because the initial stimulus was simply below the threshold for eliciting the response, then the effect is labeled sensitization.

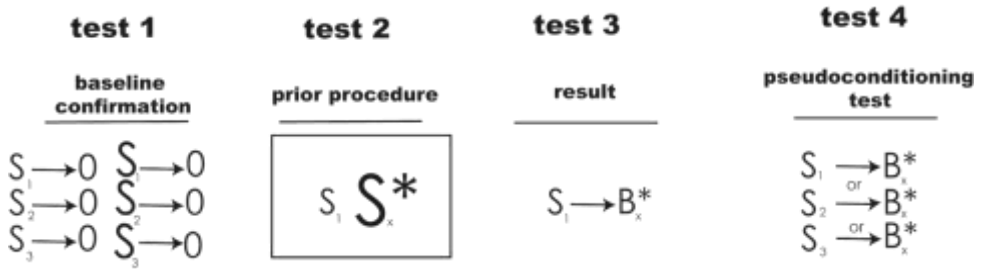


*Figure 4.20 Some stimulus presentations that do not control a reaction even when intense may have the result of enabling any of a number of stimuli to produce a response if they are presented prior to a significant stimulus. It is not considered conditioning because the acquired behavior occurs to many novel stimuli*

.

The pseudoconditioning procedure may be best conceptualized as the fact that the stimulus that was conditioned was not simply a "bell" but was rather a "change in the environment." In that case, the effect could be labeled simple conditioning because the onset of light, tone, and touch on a leg are all instances of the stimulus "change in the environment."

In any event, the effect is interesting and causes us to ponder what is meant by "the stimulus".

### 2. Dishabituation

Following habituation training, exposing the subject to any strong stimulus generally abolishes habituation and "returns the organism" to its state prior to the habituation procedure (Figure 4.21). A necessary prerequisite of this response change is that the behavior of interest had been habituated in a prior procedure.

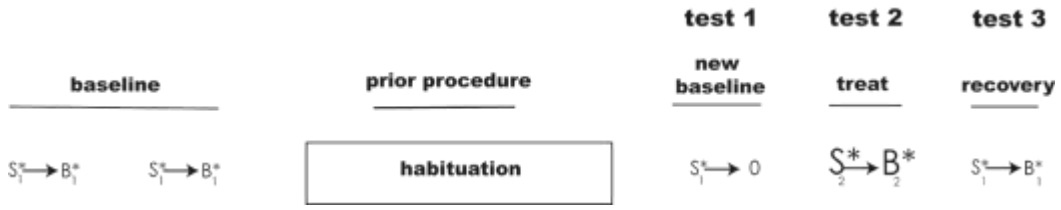


*Figure 4.21 Following habituation of a response to a stimulus, presenting a strong stimulus before re-presenting the habituated stimulus again may enable that habituated stimulus to control a response.*

### 3. Disinhibition

Following inhibition training, exposing the subject to any strong stimulus abolishes inhibitory control and "returns the organism" to its state prior to the inhibition procedure (Figure 4.22). A necessary prerequisite of this response change is that the behavior of interest had been suppressed with inhibition training in a prior procedure.

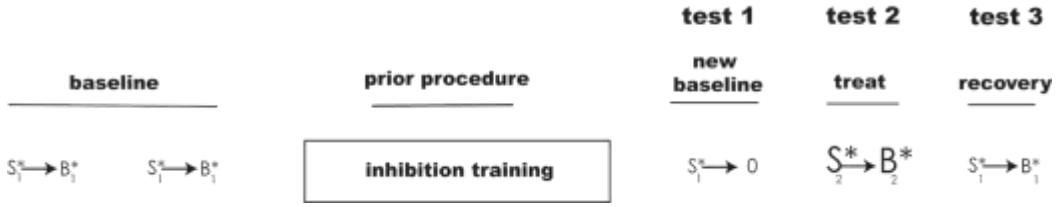


*Figure 4.22 Following inhibition of a response to a stimulus, presenting a strong stimulus before re-presenting the inhibited stimulus again may enable that inhibited stimulus to control a response.*

### 4. Spontaneous Recovery

Following extinction of a conditioned behavior exposing the subject to a rest period degrades the effect of extinction and "returns the organism" to its state prior to the extinction procedure (Figure 4.23). A necessary prerequisite of this response change is that the behavior of interest had been extinguished by a prior procedure. The recovered behavior is weaker than the original and is less enduring. With multiple spontaneous recovery procedures, the recovery is smaller with each implementation.

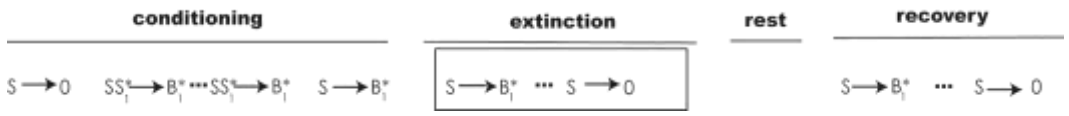


*Figure 4.23 If a behavior is conditioned and subsequently extinguished, then following a rest period it may recur with no intervening training.*

# CHAPTER 5

# Medium Time Scale Organismic Adaptation: The Emergence of Enduring Behavior Patterns or "Dispositions"

**I. Introduction to Medium Time Scale Adaptation or "Dispositions"**

**II. Formal Defining Properties of Medium Time Scale Adaptation**

**III. Trial by Trial Example of Medium Time Scale Adaptation**

**IV. Characteristics of Medium Time Scale Adaptation**

**V. The Assessment of Medium Time Scale Adaptation**

A. Factors affecting the emergence of medium time scale adaptation
B. Factors affecting the expression of medium time scale adaptation

**VI. Explanatory Framework for Medium Time Scale Adaptation**

A. Externalistic or behavior analytical
B. Internalisic (cognitive)

# CHAPTER 5

# Medium Time Scale Organismic Adaptation: The Emergence of Enduring Behavior Patterns or "Dispositions"

## I. Introduction to Medium Time Scale Adaptation or "Dispositions"

This chapter provides a very short simplistic overview of the class of functional relationships labeled medium time scale adaptation. It is depicted as the cell below short time scale organismic adaptation in Figure 5.1. This chapter should give you: 1) an unshakeable confidence that there is nothing but materialistic causation in medium time scale adaptation and 2) an understanding of what functional relationships are neither a target of research in EAB nor a source of explanation. This is an essential area of behavior change, the fact is some adaptations do not reverse at all. Unfortunately, they are under researched and poorly understood.

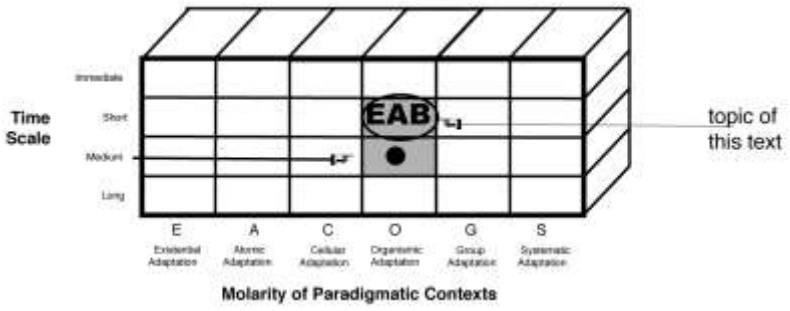


*Figure 5.1 Figure showing the relationship to EAB of the adaptation of levels of molarity below organismic adaptation (i.e., existential, atomic, and cellular adaptation) (highlighted in gray).*

A prototypical "disposition" is the phenomenon of learning to learn.

There are adaptations of behavior that require a longer time to establish or remove than short time scale adaptation, but that are not innate, rather, they require ontogenic experience. These functional relationships do not emerge as the result of genetic factors nor do they occur in the progeny.

One prototypical example is "learning to learn." This effect is demonstrated by successively reversing a discrimination. In that procedure, an organism is

reinforced for responding to green and not reinforced for responding to red. Once that discrimination is established, it is reversed i.e., red positive and green negative. Once that is established, it is reversed back. Many reversals are implemented. With increasing experiences the behavior reverses more and more quickly until it takes only a single positive or negative consequence to establish perfect stimulus control between whichever stimulus is positive and negative.

The reaction (e.g., key peck) itself is an immediate-term adaptation. The emergence of the original discriminative performance is short time scale adaptation. However, the 20th discrimination performance is not the same as the first. Medium term adaptation is exemplified by correct stimulus control following a single instance of a negative or positive outcome rather than an enduring exposure to the discrimination contingency. This acquired class of adaption requires more experience to establish or remove than short time scale adaptation.

# II. Formal Defining Properties of Medium Time Scale Adaptation

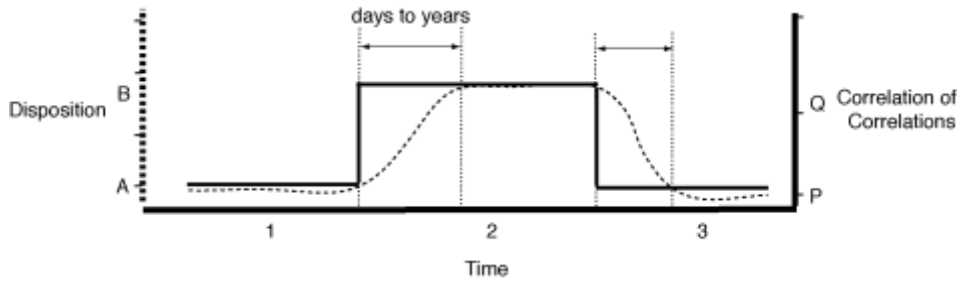


*Figure 5.2 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag in the days/years range the dependent variable 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 days/years range of the dependent variable returning to State A and again coming into equilibrium with the independent variable at Time 3.*

The measured behavior in medium time scale adaptation is a change in, or emergence of, an enduring disposition to react in some new way. It is a virtually permanent behavior change in that individual. The characteristics of medium-term adaptation illustrated in Figure 5.2. It is a re-presentation of Figure 1.6. It shows an individual coming to react in a characteristic way across a wide variety of situations (the dotted line) as the result of the independent variable. The change in the functional relationship controlling the behavior is virtually permanent for that individual. Examples would be the class of relationships that are the residual effects of short time scale adaptation such as spontaneous recovery, and the

enduring effects of successive discrimination reversals. Additional classes of this time scale of adaptation would include the disposition of "being mean" and behaviors often labeled as "automatic" such as driving a car, typing, riding a bicycle, or playing a musical instrument.

## III. Trial by Trial Example of Medium Time Scale Adaptation

Some behaviors show acquisition over the seconds-to-days time scale but do not reverse across the lifetime of the organism, or may reverse only with very great difficulty.

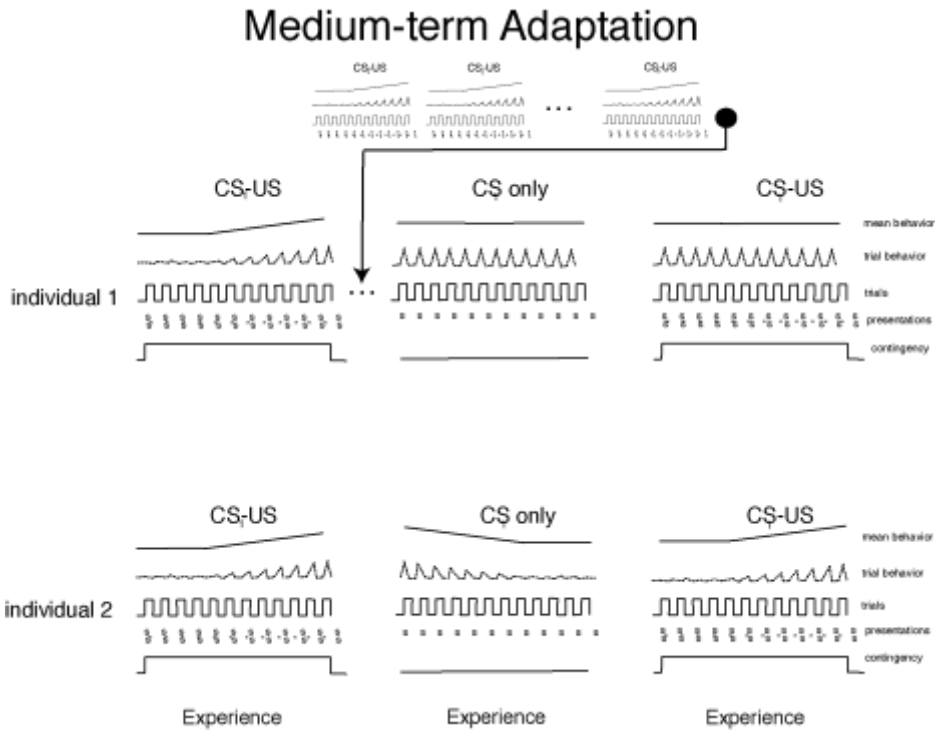


*Figure 5.3 The figure presents procedures and data from two individuals exposed to procedures in order to illustrate medium-term adaptation. The CS S* pairs along the bottom of each frame with each of the 12 square waves denoting trials in the left column represent a series of presentations of a stimulus immediately followed by the US. The single long square wave along the bottom designates instances of the experimental treatment (i.e., presenting the CS US pairs). The dotted sawtooth line above the square wave depicts instances of the behavior or dependent variable. The behavior to the CS can be seen to grow stronger with each successive trial (the height of the sawtooth gets higher). The top dotted line above the sawtooth in each frame of the left column represents the average strength of the dependent variable and documents the increase in average strength exhibited by the dependent variable. So far this is identical to the short time scale adaptation procedure. The upper individual experiences an additional wide variety of procedures with a common aspect to the contingencies as shown in the compressed section of the figure above the six main segments. The center column shows that the two individuals then experience trials with no*

*US. This is extinction. This procedure is also identical to the short time scale adaptation procedure for Individual 2. No loss of behavior occurs in Individual 1. Individual 2 shows a loss of behavior across the exposure to extinction. Finally, the right column illustrates that when given trials with CS US pairings again Individual 1 continues responding to the CS as it did throughout extinction while Individual 2 starts at zero and relearns the behavior as it had in the first phase.*

Figure 5.3 depicts the procedures and results from two subjects. In the initial phase, both children receive training trials with a procedure that provides exposure to new people who are mean. Subsequently, the first child receives numerous procedures all of which present new things such as new toys, new situations, new people, etc. all of which end badly, while the second child receives no further training. Subsequently, both children receive extinction trials where new people are not mean. The first child shows no reduction in avoidance while the second child's avoidance extinguishes. Finally, both children are re-exposed to new people. The first child exhibits avoidance before any further training while the second child initially exhibits no avoidance but subsequently re-acquires avoidance. This experiment demonstrates that some enduring functional relationship was established by the procedure received by the first child.

# IV. Characteristics of Medium Time Scale Adaptation

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 organisms 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

# V. The Assessment of Medium Time Scale Adaptation

As with research on any time scale of adaptation, the behavior of an organism is measured (the expression of a behavior). Medium-term adaptation details how functional relationships pertaining to that behavior virtually permanently changes (for that individual) with the organism's experiences with contingencies in the environment over the lifespan (Figure 5.4). Those virtually irreversible changes can be measured directly across that experience to assess factors governing the emergence of those functional relationships (how they came to be) or two asymptotic performances after different training procedures can be compared and the difference in the expressions of the functional relationship can be attributed to the difference in the contingency history between those two different groups of individuals. Note that if a training effect is permanent a single subject design cannot be used.

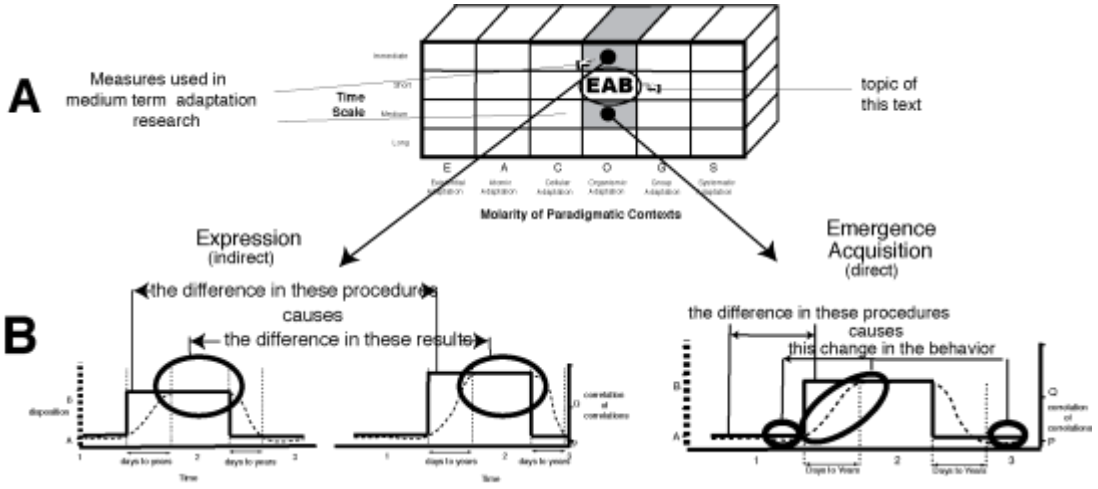


*Figure 5.4 Figure showing the relationship of medium-term adaptation to EAB. The direct measure of medium-term adaptation or its emergence is shown in the lower gray box and the right frame below the molarity by time scale structure. The measure, a reaction to a stimulus, used in the indirect assessment of medium-term adaptation or the expression of a disposition is depicted in the upper portion of the structure (immediate-term adaptation) and in the lower left of the figure.*

### A. Factors Affecting the Emergence of Medium Time Scale Adaptation

By definition, the emergence and removal of the behavior occur across the days to years time scale. Many factors can affect the characteristic of functional relationships of this time scale. For example, the number of overlapping contingencies, the variance between the contingencies, and the magnitude of reinforcement. The important detail is that the emergence of the medium term functional relationship is the dependent variable.

### B. Factors Affecting the Expression of Medium Time Scale Adaptation

The expression of a medium-term adaptation can be affected by variables typical of each time scale of adaptation. For example, characteristics of the stimuli or the similarity of the test and training stimuli, various schedules of reinforcement, previous medium-term contingencies, and innate characteristics of the organism. The important detail in this case is that the dependent variable is the difference in asymptotic performance in two different groups od individuals.

# VI. Explanatory Framework for Medium Time Scale Adaptation

Within this time scale, the focus of the explanation is on the disposition. For example, the answer to why did the pigeon peck is that the pigeon had a disposition or strong tendency to do so (the pigeon pecks a wide variety of things and the behavior is resistant to extinction).

### A. Externalistic or Behavior Analytical

In its simplest, the explanation for why the organism responded that way could be given as "the organism was exposed to commonalities of contingences that made it respond that way.

A potential independent variable for medium-term adaptation is the exposure of the organism to multiple contingencies in multiple contexts that all have a common aspect of the contingency (correlation of correlations). The measured behavior is 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 5.5 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 would be the "cause" of medium-term adaptation). Note that some of the dimensions of a reinforcement contingency could be purely adventitious. The point of the figure is that removing one circle (i.e., set of contingencies) from the right portion of the figure would not remove the contingency.

*Figure 5.5 The circle to the left represents a reinforcement contingency as noted by the asterisk. The intersection of the three circles to the right indicated with an asterisk represents*

*the shared aspects of three "different" reinforcement contingencies.*

Research could document the change in the resistance to change of a behavior as a function of the variance in various contexts with a shared reinforcement contingency.

It is critical to note that this time scale of adaptation refers to the emergence of an enduring characteristic behavior (presumably, as the result of overlapping contingencies) rather than the simple expression of a specific behavior or short time scale adaptation which is only semi-permanent and therefore readily reversible. a simple discrimination is a short time scale adaptation.

A familiar example of exposure to commonalities in contingencies resulting in a relatively irreversible change in how the subject reacts to any one contingency is Piaget's (19xx) 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 response of the child was to "see" the conservation of volume. The difference between the two different learned adaptations is the difference between short- and medium-term adaptation.

This type of adaptation is conditional on the information common to a number of reinforcement contingencies and takes more than an exposure to a single contingency. As a result, it is slower to acquire and also slower to reverse than simple learning. Whereas learning is via correlation, developmental adaptation is controlled by the correlation of correlations, i.e., multiple correlation (typically illustrated as a three, or more, dimensional scatter plot as is illustrated in Figure 5.6). Medium-term learning is based on the accountable variance across many different learning situations.

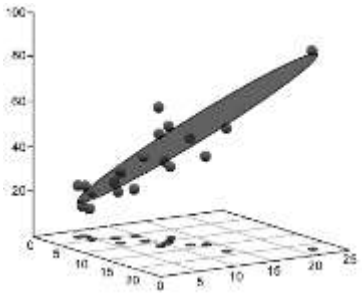

*Figure 5.6 An illustration of multivariate covariance. For example, grades in a course the y-axis (0-100) are a function of both the amount of studying (the x-axis (0-25) and the prior grade point average (the z-axis 0-20).*

There are three ramifications of this correlation of correlations conceptualization. It should be expected that substantial *z*-axis experience with a strong correlation (i.e., the additional axis or axes in multiple correlation) would vitiate the importance of relatively minute local information in an isolated contingency. Secondly, this multivariate adaptation makes least-effort/ evolutionary sense because when many different contingencies have a common

functional relationship, then that sub-contingency will effectively be factored out and the functional relationship learned "more permanently" or "taken for granted" across the life span of that individual. Finally, intermediate cases should be expected; those somewhat short time scale and somewhat medium-term, and those somewhat medium-term and somewhat long-term (such as imprinting).

It should be obvious that designs used to prove causation in short time scale adaptation (recover baseline within same subject) may not be appropriate for medium-term adaptation. Proving causation for this time scale requires substantively different research designs. For example, if we wish to study the acquisition of bicycle riding we may never be able to recover baseline within that same individual. If we cannot make the subject naïve again, we may choose to have a baseline across individuals. Multiple baseline procedures are often used to study medium-term adaptation for that reasons.

The factors that control this time scale of adaptation (as opposed to short time scale adaptation) have not been extensively researched and are not well understood. As a result, the causal factors in this time scale is more speculative than the other three time scales of adaptation.

Recall the change of change description and the computer metaphor for time scale of adaptation. A reaction to a green light going on and off is labeled a change in behavior (CIB). A learned behavior to the green light going on established by a reinforcement contingency could be designated as a C(CIB). In the medium-term adaptation case, the learned change in behavior itself is changed. For example, whereas it had originally taken 100 trials to learn to peck red rather than green, 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 metaphor, this adaptation is like a writable "DVDR." These DVDs can be written on once but after that they can only be read.

### B. Internalistic (Cognitive)

This approach creates some internal entity or stage of development such as "concrete operational" that is an internal thing causing the external behavior. This usage should not be confused with the terms used as labels for a characteristic of behavior.

# CHAPTER 6

# Long Time Scale Organismic Adaptation: The Evolution of Innate Behavior or "Instincts"

## I. Introduction to Long Time Scale Adaptation or "Instincts"

## II. Formal Defining Properties of Long Time Scale Adaptation

## III. Characteristics of Long Time Scale Adaptation

## IV. The Assessment of Long Time Scale Adaptation

A. Issues Pertaining to the Emergence of Long Time Scale Adaptation
   1. The fundamental machinery underlying the emergence of long time scale adaptation
      a. Variation
      b. Selection
      c. Non-regressive reproduction
      d. Ancillary factors governing the emergence of long time scale adaptation
   2. Example independent variables for the emergence of Long Time Scale Adaptation

B. Issues underlying research on long time scale adaptation via comparisons of the <u>expression</u> of innate behavior between species
   1. Conceptual review: logic underlying research on the expression of Long Time Scale Adaptation
      a. Requisite conditions
         i. Difference in behavior
         ii. Difference in species
   2. Example independent variables for the expression of long time scale adaptation
      a. Degree of externalization
      b. Degree of sensitivity to contextual alterations
      c. Degree of independence of eliciting and steering function of stimulus
      d. Degree of dependency on control feedback

## V. Explanatory Framework for Long Time Scale Adaptation

A. Externalistic or behavior analytical
B. Pseudo explanatory mechanism
    1. Hydraulic metaphors
    2. Control system schema

## VI. General Classes of Innate Behavior or Instincts

A. Innate reactions of a specific subsystem of the organism
    1. Reflex
B. Innate reactions of primitive organisms
    1. Kinesis (movement)
    2. Taxis (orientation)
C. Innate reactions of complex organisms
    1. Unitary modal action pattern
    2. Serial modal action patterns: reaction chain
D. Innate reactions of complex organisms with significant and essential ontogenic components
    1. Imprinting
    2. Adjunctive behavior

# CHAPTER 6

# Long Time Scale Organismic Adaptation: The Evolution of Innate Behavior or "Instincts"

## I. Introduction to Long Time Scale Adaptation or "Instincts"

This chapter provides a very short simplistic overview of the class of functional relationships labeled long time scale adaptation. It is depicted as the cell at the bottom of the organismic adaption column in Figure 6.1 This chapter should give you: 1) unshakeable confidence that there is nothing but materialistic causation at the long-term scale of adaptation and, 2) an understanding of what functional relationships are neither the target of research in EAB nor a source of explanation. The general framework for the following chapter reviews and roughly follows Mazur's learning text (which is not to say he would agree with all of this chapter).

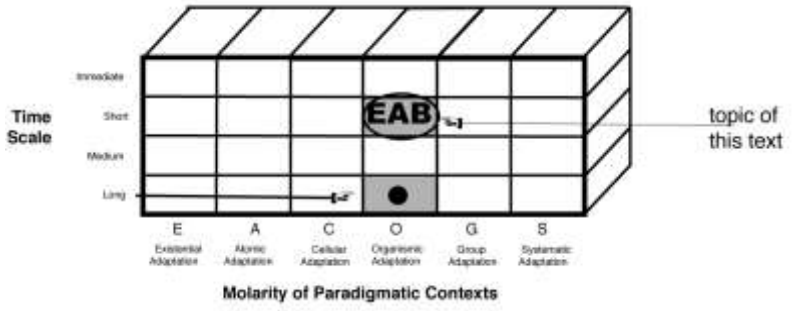


*Figure 6.1 Figure showing the relationship to EAB of the adaptation of levels of molarity below organismic adaptation (i.e., existential, atomic, and cellular adaptation) (highlighted in gray).*

A prototypical "instinct" is migration in birds. Migratory birds can be raised in an isolated indoor laboratory until mature and then released. They migrate to the same location as previous generations for the winter, in spite of having no ontogenic experience with respect to it.

The functional relationships which characterize an innate behavior are common across virtually all members of a species and require no ontogenic contingency training for their expression. They are not acquired (learned) across the life experiences of an individual, rather, they are a change in the

frequency of a behavior in the distribution of all the individuals in a population. For example, rather than 20% of the individuals in a population exhibiting a behavior from birth, 95% of the individuals exhibit that behavior from birth following the treatment.

For long-term adaptation to occur the response to a particular environmental condition the functional relationships must be stable across the species and across generations and have a reproductive impact. The functional relationship 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 and be well represented in the population. In principle, however, it could be installed and removed very quickly. For example, feral silver foxes were domesticated within 40 years. Alternatively, long-term adaptation could be the result of a single mutation in a single individual which then increases in frequency as the result of that individual having a great many offspring. If those offspring out reproduce the existing population, then that functional relationship will come to predominate.

It should be noted that the individual components of 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. Salivation to food in the mouth could have precursors which predate digestive saliva and a mouth.

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.

# II. Formal Defining Properties of Long Time Scale Adaptation

The characterization of long-term adaptation given in Figure 6.2 is a re-presentation of the original given in Figure 1.8. It shows a species acquiring (evolving) for example, 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 the result of differential reproductive success (rather than ontogenetic experience). The reflex of salivating to food (i.e., an unconditioned reflex) evolved or emerged across many generations. In the functional relationship labeled an unconditioned reflex, both the eliciting stimulus and the elicited behavior are fixed. It is not just any stimulus and any behavior. They have been selected by evolution. It is important to make clear that this adaptation is not an individual acquiring a functional relationship as the result or reinforcement and then passing that functional relationship on to its offspring. This change resulting from evolution is a change in the frequency of a functional relationship in the population and is across progeny not within an individual. It is an evolved reflex or instinct.

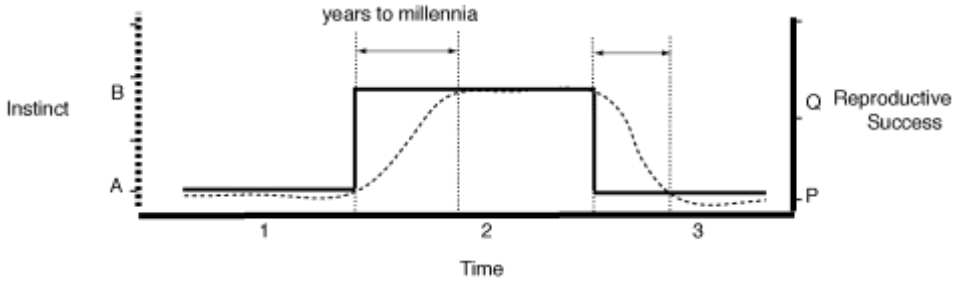


*Figure 6.2 After an initial state of equilibrium (at Time 1) between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag in the years/millennia range the dependent variable 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 years/ millennia range of the dependent variable returning to State A and again coming into equilibrium with the independent variable at Time 3.*

# III. Characteristics of Long Time Scale Adaptation

(1) the ability of a stimulus difference to control a response difference is permanently 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 in 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. This class of behavioral adaptation generally takes a very long time. (Hysteresis of years to millennia [as implemented by generations].)
(5) hysteresis in years - millennia range (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").

# IV. The Assessment of Long Time Scale Adaptation

This time scale of adaptation (i.e., long-term adaptation) is defined as how the expression of innate behavior changes or <u>emerges</u> as the result of

differential reproductive success across many generations of a population (i.e., evolution). Long-term adaptation is illustrated by the acquisition or emergence in a subsequent generation of a functional relationship such as migration, courtship patterns, or a salivary reflex over evolutionary time. It is how the functional relationship came to be. It is a transition measure.

On the other hand, the actual expression of the behavior itself e.g., the drips of saliva in the mouth of a dog when meat powder is placed in its mouth, or the migration in the spring, is an immediate time scale adaptation. It is the occurrence of a reaction when a stimulus occurs and is the dependent variable that had changed across evolutionary time as the result of differential reproductive success.

As a result, there are two ways long-term adaptation can be studied. They are illustrated in Figure 6.3. The first and direct way is to alter the reproductive success of some trait and document the details of how the frequency of the expression of the innate behavior (the functional relationship) in the population emerges, adapts, or changes over evolutionary time in subsequent generations. The second approach is to document the details of the expression of the behavior in two different species and infer that the difference in the expression of the innate behavior is a function of the difference in the evolutionary factors that had affected and created the difference in those species.

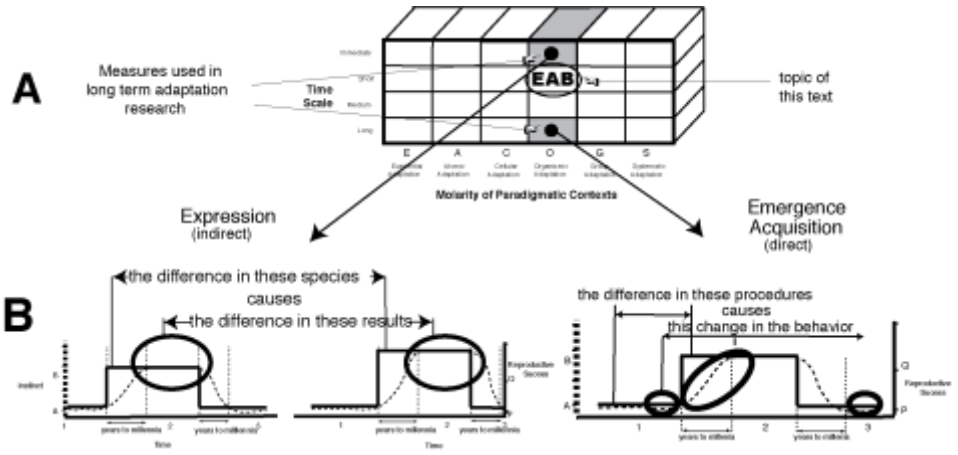


*Figure 6.3 Figure showing the relationship of long-term adaptation to EAB. The direct measure of long-term adaptation or its emergence is shown in the lower portion of the molarity by time scale structure and the lower right portion of the figure. In long-term adaptation, the change in the reaction or expression of a behavior to a stimulus (a functional relationship) is monitored across evolutionary time. The change in the expression or the emergence of a new functional relationship as the result of selective reproduction is the dependent measure. The measures to a reaction to a stimulus, used in the indirect assessment of long-term adaptation or the expression of an instinct are depicted in the upper portion of the upper structure (immediate-term adaptation) and in the lower left of the figure. The difference in the expression of an unlearned or innate behavior in two species is attributed to the difference in the species.*

Research into the expression of innate behaviors (i.e., immediate-term

adaptation) is often confused with research into the origin of the innate behavior (i.e., long-term adaptation). It is important to keep in mind the distinction between questions pertaining to the emergence or origin of a functional relationship between meat powder and salivation or how salivation to meat powder evolved, and the expression of a behavior such as salivating to meat powder in the mouth.

When the expression of an innate behavior (such as the migration patterns of geese) is the research question, it is immediate-term research, it is the subsequent explicit or implicit comparison between species with the intent to understand how that migration pattern emerged or came about that makes the research pertain to long-term adaptation.

The topics covered in this chapter (long-term adaptation, innate behaviors, or instincts) are not the functional relationships covered by the experimental analysis of behavior. The expression of the behavior of this class of functional relationships (upper gray box of Section A and left portion of the lower half Section B of Figure 6.3) has no dependence on any ontogenic contingency history. The emergence of this class of functional relationships (lower gray box of Section A and the right portion of the lower half Section B of Figure 6.3) is across individuals and evolutionary time and therefore is not short time scale adaptation either.

## A. Issues Pertaining to the Emergence of Long Time Scale Adaptation

This is the procedure used to define time scales of adaptation. It is the direct and at least at first blush, the most obvious method of assessing adaptation to some changed procedure.

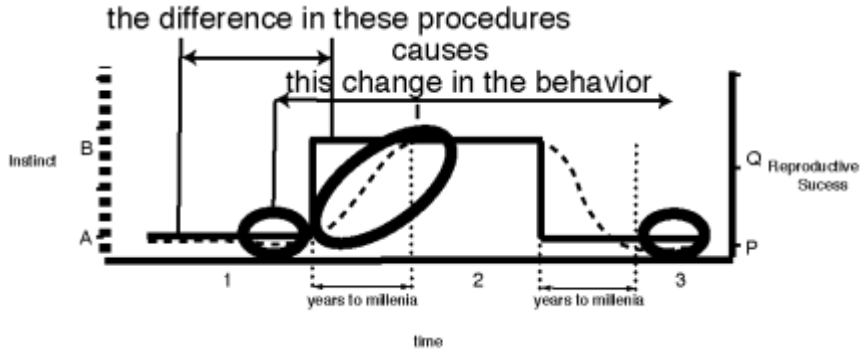


*Figure 6.4 This figure is a re-presentation of Figure. 1.18. This figure depicts the emergence or acquisition of a dependent variable (dotted line) as a function of a change in the independent variable (solid line). In sum, the difference in the dependent measure is caused by the difference in the independent 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 reversed.*

This measure illustrated in Figure 6.4 is the transition from some procedure and its resulting behavior considered a zero state to some asymptotic

performance to a different procedure. It is an x-axis measure as well as 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). It is the change in the proportion of a population exhibiting some behavior from birth as the result of a difference in the resulting reproductive success of those two conditions. The time scale extends across the life span of many generations of organisms and the dependent measure is the proportion of a population exhibiting the functional relationship long term behavioral adaptation (fixed behaviors to fixed stimuli) comes to occur across evolutionary time. Innate behaviors appear to be the "rational" acts of an "aware" being. The truth is, many of these highly adaptive behaviors can be harmful (e.g., moth to a flame) or can occur when the cortex has been removed so that even the most recalcitrant mentalists would have to accept that whatever they mean by being rational and aware could not possibly occur most typically the internal process of cellular evolution is used to explain the cause of innate behavior. Experimental long-term adaptation research based on the acquisition, emergence, or origin of functional relationships at this time scale (e.g., the salivary reflex) would require changing the reproductive success associated with various amounts or types of salivation and would likely require a very large population of subjects and very many generations to complete.

Experimental long-term adaptation research based on the expression of that acquired salivary reflex occurring would involve changing the amount, taste, or other aspects of the stimulus, and then determining how much salivation occurred when those variations of meat powder were presented to each of at least two different species. The difference in these findings across species would be expected to be informative with respect to the evolution of salivation to meat powder in those species. The difference in the reaction to the same stimulus between two species can be used to infer information about the evolutionary differences between those two species and how to extend generalizations across that species difference. For example, herbivores and carnivores have different salivations to meat powder.

In overview: fixed stimuli eliciting fixed responses (innate behavior, or instincts):

- evolved to deal with situations which reliably had the same solution over evolutionary time
- are very fast within the individual (in fact feedback often slows them down)
- are typically unaffected by short time scale consequences (e.g., frogs can be made to repeatedly lunge onto pin blocks)
- an eliciting stimulus can control a directed response (e.g., scratch reflex in a decerebrated dog is targeted to point of stimulation)

The expression of innate behavior or instincts (immediate-term adaptation) can come to be controlled by arbitrary stimuli as the result of contingencies of reinforcement between arbitrary stimuli and stimuli that control instinct such as reflexes or migration (short time scale adaptation). Establishing control over an innate response by an arbitrary stimulus is one of the focuses of EAB and is

labeled Pavlovian conditioning.

Possibly the simplest example of immediate-term independent variables on the acquisition of an innate functional relationship is stimulus intensity. A stimulus must be strong enough to be able to control a behavior to have some effect on the acquisition of an instinct. An example would be the evolution of echo location in bats. At each stage, the bats would have to be able to detect the echo. Further, that functional relationship must result in a change in reproductive success.

An example manipulation of short time scale adaptation would be to breed individuals based on their speed of learning the functional relationship for which they are being selected. The presumption being that eventually no ontogenic experience with the reinforcement contingencies would be necessary.

An example medium-term adaptation manipulation from this class would be to breed individuals based on the speed or simplicity with which they acquire the desired functional relationship as a disposition.

Long-term adaptation manipulations would be to breed individuals based on their exhibiting some other instinct. For example, begin breeding border collies with a dog breed with a very good olfactory sense in order to end up with a dog that would round up wild game in the woods.

### 1. The Fundamental Machinery Underlying the Emergence of Long Time Scale Adaptation

For example, silver foxes, which exhibit the gentlest, least excitable, or friendliest behavior of all their cohorts, could be differentially bred (artificial selection). This criterion for breeding could be repeated generation after generation. Eventually the behavior expressed in various situations by subsequent generations would change enough to be labeled domestication (it took only about 40 years!). In this case, the independent variable is the selection of gentle and friendly behavior for breeding and the dependent variable is the gentle and friendliness of subsequent generations. The procedure could return the behavior back to baseline by breeding only the most excitable and aggressive foxes. This approach is illustrated in the lower right section of Figure 6.3.

#### a. Variation

There are differences in individuals with respect to their behavior traits. This is the population dynamics of that functional relationship.

#### b. Selection

There are differences in the reproductive success of individuals with specific traits. The trait possessed by the individuals that reproduces the most effectively is labeled the most adaptive trait.

#### c. Non-Regressive Reproduction

Individuals tend to produce offspring with the same trait as their parents rather than the average traits. Additionally, their offspring tend to produce offspring with that same trait.

#### d. Ancillary Factors Governing the Emergence of Long Time Scale Adaptation

Note that many generations of selective breeding would generally but not necessarily be necessary in each case.

### 2. Example Independent Variables for the Emergence of Long Time Scale Adaptation

An example of an independent variable from cellular adaptation on the development of an instinct would be breeding individuals based on some cellular structure or process such as the density of rods and cones in their eyes to facilitate the acquisition of the behavior of reacting to weak stimuli in the resulting species. Alternatively, selective breeding could be based on lighter and lighter body weight when trying to breed the ability to fly in what started out as a pig.

An example of an independent variable at the population adaptation level of molarity on the development of an instinct would be breeding individuals from a subpopulation based on the frequencies of some functional relationship in that subpopulation that was correlated with the trait of interest with the expectation that the individuals from that subpopulation would be more likely to have the desired trait.

## B. Issues Underlying Research on Long Time Scale Adaptation Via Comparisons of the Expression of Innate Behavior Between Species

Occasionally, research effort is focused on varying stimulus conditions and documenting how behavior changes to those stimulus conditions when the functional relationships are thought to be of evolutionary origin. This is not long-term research. Rather, it is immediate-term research with the critical comparison of those functions across species left to another stage of the research or other investigators. It only becomes long-term adaptation research when the species comparison is made and inferences concerning evolution are made based on the difference in behavior related to the difference in species. While the single species database is essential for understanding long-term adaptation, it does not bear on the topic of long-term adaptation without explicit or implied comparison between species.

By far the most frequent approach to studying innate behavior is to compare the expression of various functional relationships of genetic origin from one species to another.

### 1. Conceptual Review: Logic Underlying Research on the Expression of Long Time Scale Adaptation

The second approach to assess the adaptation of an organism's behavior is to observe and document the expression or equilibrium / asymptotic behavior. This is when asymptotic behavior of one species is subsequently compared to the equilibrium behavior maintained by the same stimuli in a different species as is illustrated in Figure 6.5. It is then assumed that the difference in the behavior resulted from the difference in the species.

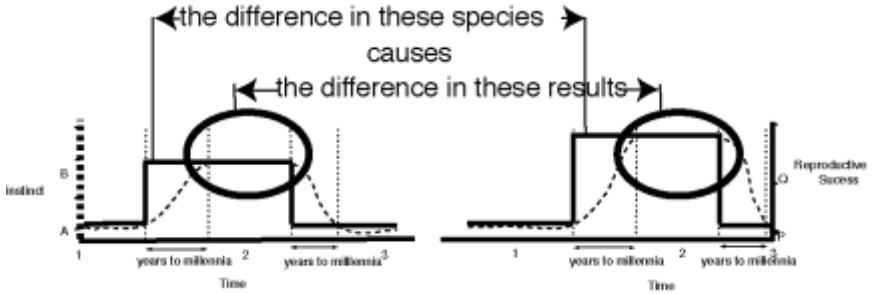


*Figure 6.5 This figure is a re-presentation of Figure. 1.19. This figure depicts the difference in the asymptotic expression of a dependent variable (dotted line) as a function of a difference in the independent variable (solid line, i.e., species). In sum, the difference in the dependent variable is caused by the difference in the species.*

The eliciting stimulus is presented to each of two species. The difference between the obtained response in those two species is measured.

The functional laws pertaining to innate behavior are most typically determined by documenting how the two species differ with respect to how the response changes as a function of changes in the properties or context of the stimulus (i.e., immediate time scale manipulations). Alternatively, two different species would be exposed to the same learning task and how those two species differed with respect to how they learned would be assessed. In either case, the functions obtained with one species are compared to the results obtained with some other species (thus the term "comparative" psychologists).

An analogous approach to the study of behavior whose origin was the result of short time scale adaptation would be to detail aspects of the differences in the behavior of two individuals who had had different discrimination training. First, two individuals would each be given some different discrimination training (the mystery so to speak), then each individual would be given an exposure to some stimulus (the data collection). Finally, the difference in the reaction to the test stimulus in the two individuals would be used to infer what the difference in the mystery discrimination procedure was.

In both types of research, (on instincts and on learned behavior), the actual task would be to identify the environmental events that caused the behavior to emerge in both individuals based on how the behavior to the test situation differed in those two individuals. The task would then be to develop a systematic framework with which to successfully predict into any possible situation.

#### a. Requisite Conditions

##### i. Difference in Behavior

The first step, of course, is to measure and document a difference in innate behavior between two species to the same stimulus.

##### ii. Difference in Species

The functional properties of the two obtained functional relationships are then compared to the evolutionary difference in those two species. In that way, the difference in a behavior (its expression) is seen as the result of a difference in their evolution (its emergence).

Note that this essential comparison between species is often deferred to some other researcher or to some later time.

### 2. Example Independent Variables for the Expression of Long Time Scale Adaptation

The expression of an innate behavior such as threat behavior in one variety of ducks could be compared to the expression of threat behavior in similar varieties of ducks so that the long-term contingencies that established that behavior could be understood. In this case, the independent variable is the difference between the different species selected and the dependent variable is the difference in the expression of threat behaviors.

#### a. Degree of Externalization

Many innate behaviors such as reflexes are governed by external stimuli such as the light cycle or contact with some environmental stimulus. Many other innate behaviors are controlled by internal stimuli and have some internal behavior as their result.

#### b. Degree of Sensitivity to Contextual Alterations

Many factors alter the likelihood of a reflex or modal action pattern occurring to a stimulus. This makes the behavior of the organism very much more adaptive. These adjustments do not require ontogenic training and are common across virtually all members of a species.

The stretch reflex will not occur if it produces pain.

Male sticklebacks will not court a female until after they have built the nest, at that point they will court females, however, they will attack the female after egg laying.

### c. Degree of Independence of Eliciting and Steering Function of Stimulus

Examples of the eliciting and target being the same are sticklebacks attack an intruder, moths fly toward light and a stimulated arm moves away from a heat source.

Examples of the eliciting and target stimuli being different are cichlid hatchlings approach black spots on mother fish regardless of the source of looming objects, compass orientation in ants, and "Reflex figure" or stepping away reflex in mammals.

### d. Degree of Dependency on Control Feedback

Some behaviors have a substantial dependency on control feedback. For example, the side-to-side adjustment in egg retrieval in gray lag geese is governed by the movement of the egg, and will not occur unless the egg rolls to one side; nursing in infants is governed by the presence of a nipple; and vestibular reflex maintains head orientation with respect to gravity.

On the other hand, some behaviors have a minimal dependency on control feedback. For example, pulling the neck in during egg retrieval in gray lag geese is independent of the continuing presence of the egg once the behavior is initiated; spiders spin cocoon independent of the functionality of the actual cocoon; and pupillary contraction occurs even if it produces an increase in brightness.

# V. Explanatory Framework for Long Time Scale Adaptation

### A. Externalistic or Behavior Analytical

This explanatory approach is the specification of the phylogenic relationship among inputs and outputs such as the reproductive success of specific behaviors and the factors necessary to generalize the knowledge to other situations. Ontogenic contingences are not considered in this time scale. Figure 6.6 provides a simple version of this approach. It does not suggest how the input and output are "connected internally" or specific cellular changes that were selected by evolutionary processes. It is entirely externalistic. For example, if only friendly foxes are permitted to breed, then it would be expected that the probability of friendliness would increase in subsequent generations. Note that no internalisms are necessary. The researcher could (justifiably) say I have no idea what internal thing caused the change and I don't even care. I know how to change the contingencies in the environment to affect the change. Breed friendly foxes with friendly foxes and have more friendly/friendly matings than any other. Eventually the entire population will be friendly from birth.

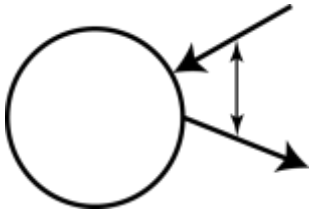

*Figure 6.6 The occurrence of stimuli, or the relationship among stimuli, or the relationship of the organism's behavior to the occurrence of stimuli can be shown to be necessary or sufficient to cause the behavior of the organism and are therefore the data elements of exclusive interest to Behavior Analysis.*

This explanatory approach could simply provide a table or an equation that specifies how the dependent variable varies as a function of values of the independent variable and how extensions or generalizations beyond the specific data may change that function. Because only empirical relationships are specified, the database of this class of explanations is necessarily correct, and will not change with a change in explanatory fads. Behavior analytic explanations for the emergence of long-term adaptation entail the functional relationships relating to variation, selection, and non-regressive reproduction and any necessary ancillary factors necessary to provide for generality.

### B. Pseudo-Explanatory Mechanism

There are two popular conceptual metaphors used in discussions of fixed behaviors occurring to fixed stimuli. They are necessarily "correct" because the referents for those "explanations" are adjusted after the fact based on obtained empirical evidence until they are consistent with the obtained results. It should be noted however, that this eliminates the possibility of these tautological statements being used as meaningful explanations.

A second failure in these metaphors is that they distract attention away from the details of the functional properties (i.e., functional analysis) toward the imagined details of some imagined internal process. Recall the discussion about the criteria by which explanations and models should be evaluated, such as their necessity to be non-tautological, testable, and providing an objective process.

Recall also that while some researchers were making up internal cognitive processes about egg retrieval, other researchers were carrying out a functional analysis of egg retrieval and discovered the stimulus properties that maximized and minimized the behavior (thus explaining it).

#### 1. Hydraulic Metaphors

The first internalistic metaphor is hydraulic. It is simplistic, dated, and surely wrong, but it is a metaphor that is intuitively satisfying to the lay and provides an ability, after the fact, to make up a sequence of events that seems

like it could be the explanation for the behavior. Unfortunately, that is little more than saying it works when it works. Its only value of this type of pseudo-explanation is in its ability to satisfy the lay.

The initial exemplar of this class of metaphors is the Cartesian explanation that asserts that some prompting stimulus such as fire on a child's toe causes a buildup of neural pressure that travels up to the brain. The pressure is reflected back. That, in turn, causes energy to travel down to the leg muscle causing it to contract thus pulling the leg from the fire.

Alternatively, the hydraulic pressure function is illustrated as the build-up of water pressure in a reservoir (the energy to do some behavior) that is in turn released by something that activates a release valve (a releasing stimulus that activates some innate behavior). The released water then can accomplish work or cause an innate behavior to occur.

### 2. Control System Schema

The second internalistic metaphor is a control system. Figure 6.7 provides a schematic of an example. It is surely right in that whatever is the ultimate truth will be able to be described as a control system, but in the absence of the specification of exactly what output is expected as a function of what input and what physiological systems implement those processes before the fact, it is too vague to be very useful. Creating, post hoc, each of the steps thought to intervene between input and output adds nothing to our knowledge base and is, therefore, a tautology.

Figure 6.7 is a control system to maintain the temperature in a room.

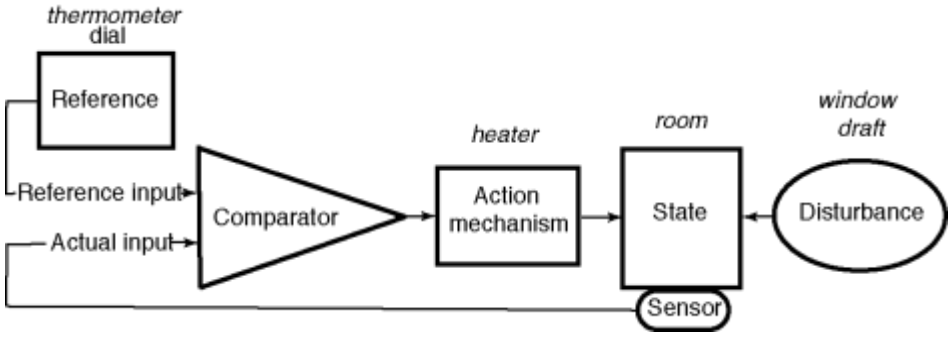


*Figure 6.7 A figure illustrating a control system (in this example a temperature control system). The reference mechanism puts the set point (desired temperature) into a comparator. If activated, the comparator turns on the action mechanism (the heater). The state of the thing being controlled is altered by the action mechanism (temperature of the room). The disturbance mechanism (window draft) can change the state of the thing being controlled (temperature of the room). A sensor (temperature sensor in the thermostat) detects this change in the state of the room (temperature) and sends it to the comparator. If the temperature is equal to or higher than the set point, the heater shuts off. If the temperature is lower than the reference input, then the heater turns on (Mazur, 2006).*

# VI. General Classes of Innate Behavior or Instincts

Recall that experimentation on the origin or emergence and loss of a behavior as a function of evolutionary factors is almost never done. Rather, the difference in how the behavior adapts as a function of immediate time scale factors (the expression of the behavior) between two different species is the typical functional relationships studied. In fact, once the functional relationship is determined to be innate, the categorization of various behaviors is typically based on factors related to the expression of those behaviors rather than on the factors affecting their origin or emergence.

Each of the following seven environment-behavior relationships (or categories of innate behavior) detailed below in sections A through D would have as their most complete context:

1) the defining characteristics of the environment/behavior class of interest,
2) for the emergence or origin of the functional relationship
   a) illustrative research, showing a change in a measure of the innate behavior across evolutionary time as a function of independent variables from whatever level of molarity and time scale on which the selection was based
   b) conceptual metaphors advanced in lieu of explaining the behavior
3) for the expression of the functional relationship
   a) characteristics of the stimuli that control the expression of the behavior
   b) degree of sensitivity to contextual alterations
   c) degree of independence of eliciting and steering function of stimulus
   d) degree of independence from control feedback

## A. Innate Reactions of a Specific Subsystem of the Organism

### 1. Reflex

A reflex is a simple, relatively fixed, virtually inevitable, stereotyped movement or activation of a part of the body (a fixed response) in response to a relatively specific simple stimulus (a fixed stimulus) (Figure 6.8). An eliciting stimulus is said to elicit the response. The response to the stimulus is not acquired as the result of ontogenic experience. The functional relationship occurs in virtually every member of the species; for example, pupillary contraction to light. Reflexes are somewhat atypical of the behaviors discussed in this chapter because reflexes are often actions of a part of the organism but are considered as the action of the whole organism.

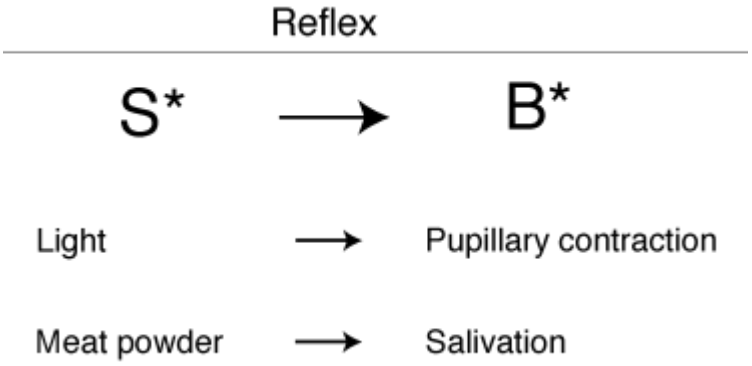


*Figure 6.8 A fixed stimulus elicits a fixed response. The functional relationship is of evolutionary origin and exists in virtually every member of a species. In a reflex, the functional relationship pertains to a subsystem of an organism. Examples are provided in the lower portion of the figure.*

Sechenov and Sherrington (as well as Pavlov in the early portion of his career) studied how a fixed stimulus elicited a subsequent fixed response. Their studies were examples of examining functions in the immediate time scale.

A reflex is a unitary behavior of evolutionary origin.

### B. Innate Reactions of Primitive Organisms

#### 1. Kinesis (Movement)

A kinesis is an overall undirected body movement. It is not oriented with respect to the source of the stimulation; rather it has a random orientation, and is only "engaged" by the stimulus (Figure 6.9). Stimuli affect the overall class of behavior, but not its orientation. Orthokinesis is a change in the rate of a behavior. Klinokinesis is a change in the rate of turning.

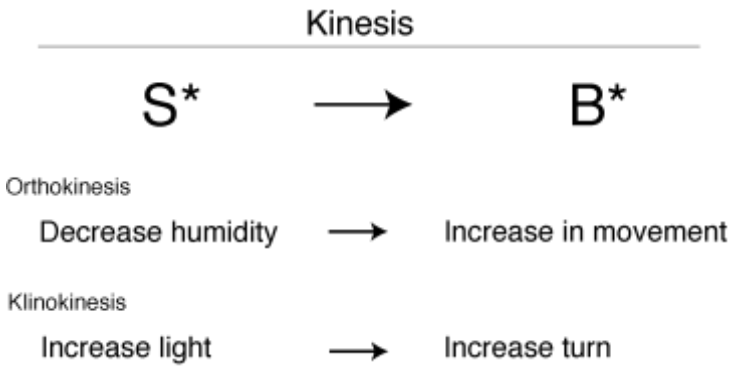


*Figure 6.9 A fixed stimulus elicits a fixed response. The functional relationship is of evolutionary origin and occurs in virtually every member of the species. In a kinesis, the functional relationship pertains to movements of an entire simple organism. Examples are provided in the lower portion of the figure.*

The distinction between a reflex and a kinesis is somewhat arbitrary, but a reflex is seen as simpler, activates only a part of the body, is less extended in time, and is not generally involved in relocating the entire organism with respect to some environmental determinant.

### 2. Taxis (Orientation)

A taxis is an overall stimulus directed body orientation (Figure 6.10). Technically, the orientation is the tactic behavior. The locomotion is non-tactic. For example:

- a moth orienting toward a light
- an earthworm turning away from light
- a maggot pointing away from light
- a tree snail orienting away from gravity (pull on shell)
- an ant orienting in a straight line at a constant angle to sun

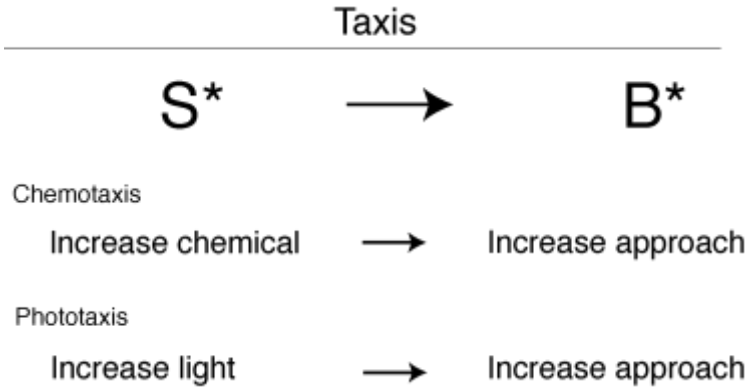


*Figure 6.10 A fixed stimulus elicits a fixed response. The functional relationship is of evolutionary origin and occurs in virtually every member of the species. In a taxis, the functional relationship pertains to orienting in a simple organism Examples are provided in the lower portion of the figure.*

Several taxes are recognized:

Klinotaxis. Successive comparisons of light on either side of body via pendulum-like movements

Tropotaxis. Simultaneous comparison of amount of stimulation on both sides of body without side-to-side movements.

Telotaxis. Animal orients to one or two light sources even with one eye.

Menotaxis. Animal orients at a constant angle to the light source.

The distinction between a kinesis and a taxis is that a kinesis is undirected whereas a taxis is directed.

### C. Innate Reactions of Complex Organisms

#### 1. Unitary Modal Action Pattern

The distinction between modal (fixed) action patterns (MAP) and a simple reflex is somewhat arbitrary but a reflex is: seen as simpler, activates only a part of the body, is less extended in time, and does not involve an extended sequence of interrelated behaviors. A modal action pattern differs from a kinesis and a taxis in that the latter are simple functions which only reorient or relocate simple organism, whereas a modal action pattern are applied to more complex organisms and could be any of a wide variety of behaviors, including the many complex behaviors necessary to relocate birds to a different hemisphere during different seasons (Figure 6.11).

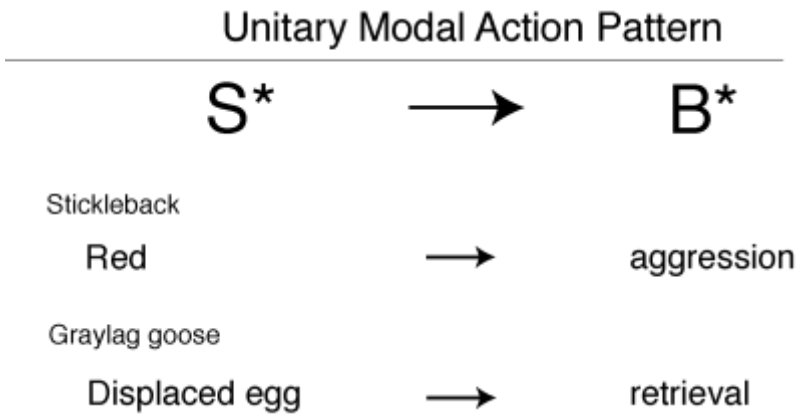


*Figure 6.11 A fixed stimulus elicits a fixed response. The functional relationship is of evolutionary origin and occurs in virtually every member of the species. In a unitary action pattern, the functional relationships pertain to the behavior of a complex organism. Examples are provided in the lower portion of the figure.*

An example modal action pattern is a Herring Gull chick's pecking at a red dot located near the end of the adult's beak in the absence of any training or reinforcing history.

### 2. Serial Modal Action Patterns: Reaction Chain

This category refers to complex behavioral adaptation that is in actuality a series of isolated MAPs under the control of a series of stimuli each of which is virtually always produced by the successively elicited behaviors (Figure 6.12).

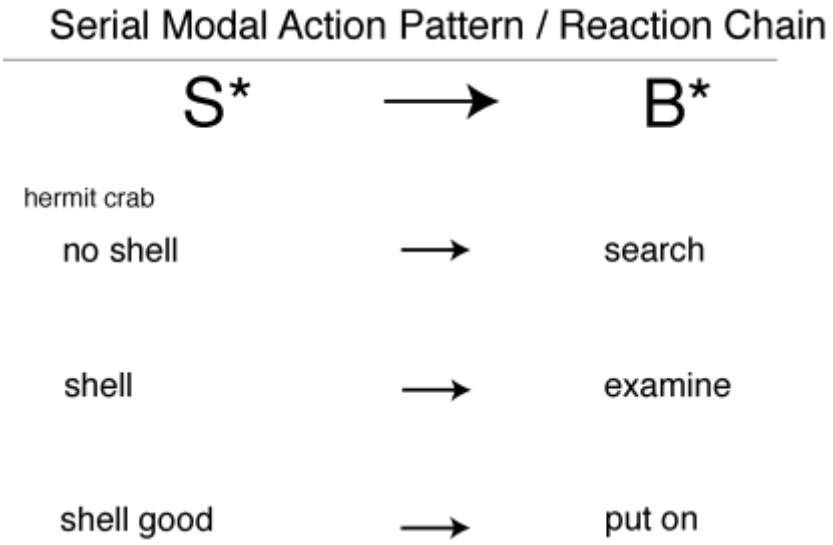


*Figure 6.12 A fixed stimulus elicits a fixed response. The functional relationship is of evolutionary origin and occurs in virtually every member of the species. In a serial action pattern, the functional relationship is best seen as a series of consecutive unitary action patterns where the output of one step inevitably produces the stimulus that releases the next step in the chain. Examples are provided in the lower portion of the figure.*

Each reaction continues until a new stimulus that, in turn, elicits the next response. For example:

Hermit crabs without shells:
have no shell → locomote
see a shell → approach shell
touch shell → explore shell
external OK → search for hole
hole full → dig out hole
empty hole → try on shell

### D. Innate Reactions of Complex Organisms with Significant and Essential Ontogenic Components

#### 1. Imprinting

This category of innate behavior refers to the fact that exposure to a stimulus within a temporal window (typically early in life) will come to control a response usually throughout the rest of the animal's life (Figure 6.13). This behavior could be seen as an MAP that is targeted as a result of ontogenic exposure. This exposure also alters the functionality of that stimulus in the future especially with respect to the target of courtship. The prototypical example is ducklings come to follow anything moving when they hatch out and will court that stimulus when an adult. Imprinting straddles the fixed stimulus producing fixed response and arbitrary stimulus producing a fixed response category.

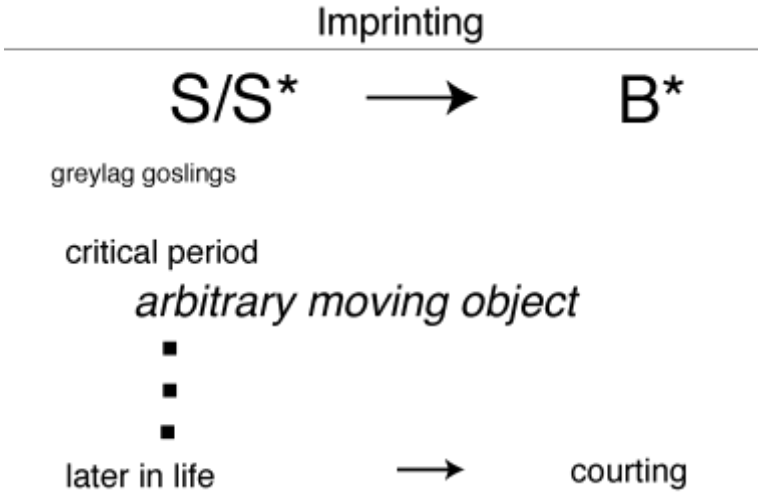


*Figure 6.13 An arbitrary stimulus comes to elicit a fixed response as if the stimulus response relationship were of evolutionary origin. The capacity for the functional relationship is of evolutionary origin. The capacity for the functional relationship exists in virtually every member of the species (the only flexibility is the precise characteristics of the eliciting stimulus). A example is provided in the lower portion of the figure.*

Imprinting is similar to a taxis in that the stimulus controls a directed behavior, but it is like learning in that it requires specific ontogenic experiences to define the stimulus. Imprinting is placed in this level of the organizational structure of this text because the altered functionality of the stimulus is not the result of learning via repeated exposures to correlations in the environment. It is due to simple exposure to the stimulus. Imprinting is also atypical of the general category in this chapter of the text in that the first effect of the exposure may occur many years later.

### 2. Adjunctive Behavior

Adjunctive behavior is the intrusion of some apparently anomalous reflexive like behavior into a procedure that did not originally control that behavior (Figure 6.14). The occurrence of this functional relationship requires a context-establishing operation. After extended exposure to some specific procedure (the establishing operation), a reflexive behavior emerges. It is as if the threshold for the elicitation of the apparently anomalous behavior is decreased by the extended exposure to the context-establishing phase. The required ontogenic establishing phase makes this functional relationship somewhat atypical of the others in this chapter.

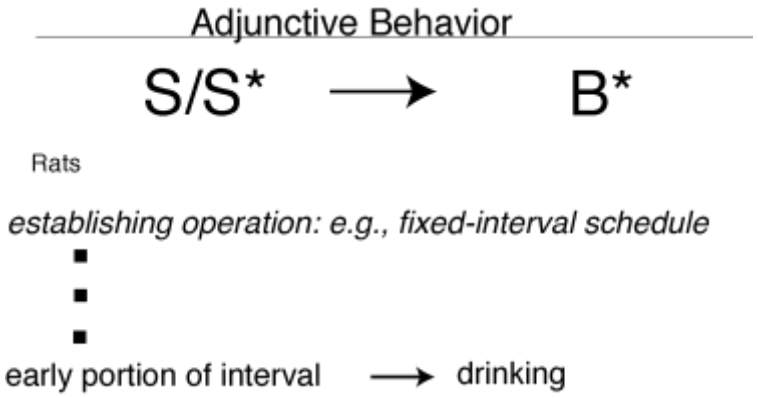


*Figure 6.14 An arbitrary stimulus comes to elicit a fixed response as if the stimulus-response relationship were of evolutionary origin. The capacity for the functional relationship is of evolutionary origin. The capacity for the functional relationship exists in virtually every member of the species the only flexibility is the precise characteristics of the eliciting stimulus. An example is provided in the lower portion of the figure.*

# CHAPTER 7

# Historical Foundations of the Experimental Analysis of Behavior

## I. The Evolution of the Initial Explanatory Framework for Behavioral Adaptation

A. The cause of all behavior of all things via God's direct will (primitive)
B. The cause of all behavior of all things via internal will (Thales)
C. The belief in dualistic existence (Plato)
D. The cause of all behavior of non-living things is materialistic; the cause of all behavior of living things is internal will (Galileo)
E. The cause of all behavior of everything except human voluntary behavior is materialistic (Descartes)
   1. Conceptual follow-up: the principled implications of Descartes' view of the cause of behavior
F. The cause of everything is materialistic (Hobbes)

## II. Evolution of the Early Explanations for Behavioral Adaptation

A. Conceptual overview: materialistic (physical or natural world) causation of behavior
B. Conceptual overview: internal mentalistic causation of behavior (an assumed cause with no objective support or that is Ganz andere)
C. Mentalistic atomistic causation (all human behavior as the combination of component acts and the result of the mind)
   1. Phylogenic experience most important determinant of human behavior (nativism)
      a. Evolution of thought
         i. Plato
         ii. Descartes
         iii. Summary
   2. Ontogenic experience most important determinant of human behavior (empiricism) (associationism)
      a. Evolution of thought
         i. Aristotle
         ii. Hobbes
         iii. Locke
         iv. Summary

b. Principled issues raised by emphasis on ontogenic experience as the cause of human behavior
i. Translation of material world to mental world: sensation and perception
(1) Stimulus detection
(a) Weber
ii. Construction of complex mental world: associationism
(1) A "perception" as a combination of more basic elements
(a) Evolution of thought
(i) Muller
(ii) Helmholtz
(2) A "cognition" as a combination of more basic elements
(a) Evolution of thought
(i) Aristotle
(ii) James Mill
(iii) Brown
(iv) John Stuart Mill
c. Subsequent philosophical and experimental developments concerning the ontogenic causation of human behavior
i. Spencer
ii. Ebbinghaus

D. Materialistic atomistic causation (all behavior including human as the combination of acts and the result of the environment)
1. Evolution of thought
a. Swammerdam
b. Sechenov
i. Conceptual coordination: Sechenov's resolution of three of the four failures in Descartes' explanation of behavior
(1) Energy out is not equal to energy in
(2) Complexity out is not equal to complexity in
(3) The absence of a causal stimulus for voluntary behavior
(4) The behavioral result of a stimulus can change
c. Mach
d. Sherrington

E. Mentalistic holistic causation (behavior only as a whole and is the result of the mind)
F. Materialistic holistic causation (behavior only as a whole and is the result of the environment)
G. Conceptual follow-up: breadth of analysis
H. Summary
1. Pre-Darwin status of theorizing: mental paradigm
2. Pre-Darwin status of theorizing: material paradigm

# CHAPTER 7

# Historical Foundations of the Experimental Analysis of Behavior

This and the next chapter provide an adapted summary of Howard Rachlin's conceptualization of the history of the Experimental Analysis of Behavior. Refer to his text for the original and more detailed treatment of the following material. Consider the following sections on the history of the field as a study guide for his or some other text. You really should read his book, or at least some other book on the history of psychology. It is not suggested that he would have agreed with everything in this chapter.

The purpose of this and the following chapter is to give you a quick overview of the historical evolution of materialistic explanations in psychology so that you can understand why things are now conceptualized as they are. Behavior analysis is not only one of many equally useful views, rather it is the winner of a very long battle to most productively understand behavior.

The cause of a thing is often essential to know, for example, why does it rain? Why did my cow get sick? What is fire? These types of questions are very difficult for the ignorant to answer. As a result, people often make up, or allow themselves to be talked into believing that gods, demons, aliens, or magic cause those otherwise mysterious things. These animisms give those ignorant people a feeling that they understand why things behave as they do and even gives them a belief that they can better their lives by controlling how things behave by burning incense or sacrificing their own children.

The history of science is: 1) the steady inexorable repudiation of superstitious or magical causation by knowledge, and 2) coming to know the actual physical world or materialistic, albeit sometimes difficult to understand, cause of the behavior of things. As a result, the history of science is also the steady progress in humans being able to control nature and to benefit by that control.

First, scholars came to realize that rocks moved by natural forces rather than by some god, demon, or magic. Subsequently, one after the other superstitions and magic were banished as causal factors in successively more complex systems. It became clear that the cause of each thing no matter how complex or baffling was actually a physical or materialistic process in the natural world. Currently, behavior analysis can be seen as replacing the mind and its minions as a cause of behavior with the actual natural world materialistic causes.

The point of this chapter is to enable you to see the evolution in explanations from primitive superstition to the realization that all things are the result of

materialistic causation. As a result, it provides you a sense of where we are and why we ask the questions we do by understanding how we got to where we are.

# I. The Evolution of the Initial Explanatory Framework for Behavioral Adaptation

## A. The Cause of All Behavior of All Things Via God's Direct Will (Primitive)

| Action Via God's Will | | | | | |
|---|---|---|---|---|---|
| Non-living | Living | | | | |
| Rolling Rocks | Swaying trees | slithering worms | Jumping chimps | Jerking humans | Talking humans |

*Figure 7.1 Figure showing the causal factors underlying the behavior of various things. In this case, all behavior was thought to be by the direct intervention of God.*

Figure 7.1 illustrates that the very earliest notions of nature suggested that all things were either living or non-living and that the activities of all things were due to god's specific will (i.e., a rock rolled down a hill because god was looking at that specific rock at that specific time and effectively said "you there rock, roll down the hill").

Causation was via God's will.

## B. The Cause of All Behavior of All Things Via Internal Will (Thales)

| Action Via Internal Will (Animism) | | | | | |
|---|---|---|---|---|---|
| Non-living | Living | | | | |
| Rolling Rocks | Swaying trees | slithering worms | Jumping chimps | Jerking humans | Talking humans |

*Figure 7.2 Figure showing the causal factors underlying the behavior of various things. In this case, all behaviors were thought to be caused by the internal will of that thing.*

Thales (624-546 BC) broke from the primitive view. As illustrated in Figure 7.2, he argued that events occurred for their own reason not simply as the result of God's will. One instantiation of his perspective was that each thing had its own internal will. An alternative (and more correct) view would assert that each action was the result of the specific external natural forces acting upon that specific thing.

Thales' choice of an internal cause for action (e.g., a rock rolled down a hill because that rock decided to roll down the hill on its own. Effectively the rock

said to itself "I guess I will roll down the hill now") was an enormous impediment to progress in understanding nature that plagues psychology to this day.

To Thales, causation was via an internal will.

### C. The Belief in Dualistic Existence (Plato)

| Material World | | | | Ideal World |
|---|---|---|---|---|
| Rocks | Trees | Worms | Chimps | Human Mind |

*Figure 7.3 Figure showing the nature of existence. The human mind was thought to be the expression of the ideal world and was not empirical while all other things were thought to exist in the natural world.*

Plato (427-347 BC) suggested (Figure 7.3) that 1) existence was separable into material things (a chair) and the ideal of that thing (a "Chair"), and 2) the ideal of each thing was available in the human mind. The machinery underlying this view (i.e., the mind) reified the dualism that was implicit in the causal machinery first postulated by Thales. Recall that the rock rolled down the hill because something inside it wanted to, and a person talked because something inside them wanted to talk. Both of these causal systems required an entity "the mind," to be able to exist inside a rock as well as existing inside a human. That entity would have to be outside the natural world because there are no places inside a rock where a natural world "thinking" entity could exist.

It should be emphasized that the existence of a mental world was Plato's version of Thales' opinion, rather than a fact of nature. This bears repeating. No known fact supports the view that there are two kinds of existence. For example, Democritus, a contemporary of Plato was a monist. He considered it self-evident that there was only one kind of existence.

A plausible explanation for Plato's notion of the "ideal" was in order to account for generalization or "classes" (e.g., how is it that I can go through a furniture store and label things as chairs or not chairs even though the various chairs are widely different and I was never told anything about those items. This is often expressed as "I have an idea in my mind of "Chair" that transcends any particular "chair"). This machinery is of course a tautology, i.e., "I know something because it's in my mind. How do I know I have a mind? Because it knows things." In modern times, generalizations and classes are well understood (see Guthrie, for example) and do not require an ideal of a thing (i.e., a "Chair") that resides in some other form of existence (i.e., the mind).

### D. The Cause of All Behavior of Non-Living Things is Materialistic; the Cause of All Behavior of Living Things is Internal Will (Galileo)

| Action Via Material World | Action Via Internal Will | | | | |
|---|---|---|---|---|---|
| Non-living | Living | | | | |
| Rolling rocks | Swaying trees | Slithering worms | Jumping chimps | Jerking humans | Talking humans |

*Figure 7.4 Figure showing the causal factors underlying the behavior of various things. In this case, the cause of the behavior of non-living things was thought to be in the natural world. All other things were thought to behave because of their internal will.*

Galileo Galilee (1564-1642) started the long, hard road back from the pit Thales had dug and Plato jumped into. Figure 7.4 illustrates that Galileo realized that: (1) some things in nature could be understood, (2) the way to understand them was by observing them (do experiments) rather than simply believing whatever the church said, and (3) that non-living things in nature behaved according to natural causes in the environment acting upon them and that those environmental causes were lawful; that is, that laws could be discovered and understood. To Galileo, the rock rolled down the hill because some force in nature pushed it or whatever was holding it there was released by something in nature.

This realization was prompted by the finding that the activities of nonliving things were completely describable, predictable, controllable, synthesizable, and explainable (i.e., could be put into a larger, reliable systematic context or "understood").

He was almost burned alive by the church for: 1) not automatically believing whatever the church told him to believe, and 2) suggesting that knowledge flows from observation and experimentation rather than what you are told by the church. Galileo had enormous courage and helped mankind take a giant step forward. 400 years after the church threatened to burn him alive for his views, the church has finally accepted that his simple realization was self-evident rather than satanic.

Galileo's view of causation was dualistic. Causation of non-living things was entirely materialistic or from the natural world while causation in living things was via an internal will.

## E. The Cause of All Behavior of Everything Except Human Voluntary Behavior is Materialistic (Descartes)

| Action Via Material World | | | | | Action Via Internal Will |
|---|---|---|---|---|---|
| Material World | | | | | Mental World |
| Non-living | Living | | | | |
| Rolling rocks | Swaying trees | Slithering worms | Jumping chimps | Jerking humans | Talking humans |

*Figure 7.5 Figure showing the causal factors underlying the behavior of various things. In this case, all things except for human voluntary behavior were thought to be caused by natural events in the natural world. Human voluntary behavior was thought to be caused by an internal will.*

René Descartes (1596-1650) tried to develop a systematic explanation for the behavior of living things (Figure 7.5) that followed Galileo's explanation of causation in nonliving things. He suggested that the behavior of almost everything in nature is caused by environmental events and follow simple natural physical laws like rocks rolling down a hill; in those cases, the entities themselves were "passive." Descartes extended Galileo's view from nonliving things to include almost all the behavior of all living things. The behavior of all animals and much of human behavior were simple stimulus-response reflexes: "stimulus in response out". Environmental events were REFLECTED as behaviors (therefore, the word "reflex"); these behaviors were involuntary and "mindless." The closest metaphor would be throwing a ball at a wall. Throwing the ball would be the stimulus. The pineal gland was the wall and the ball bouncing back was the response. A second example would be a child's mechanical bank into which you roll a coin (stimulus) that rolls through a channel and counter weights the arm that causes it to doff its hat (response). In these cases, the immediately preceding environmental event caused the behavior. The living system was nothing more than a "mirror" that reflected inputs. Many examples of this type of system are available on YouTube as kinetic art

The enormous explanatory power of this simple mechanical input/output or "reflex" conceptualization is best appreciated by considering the many behaviors of both living as well as nonliving things that can, in fact, be predicted given nothing more than the immediately preceding stimulus. Given a push, a rock rolls down a hill. Given light in the eye, the pupil contracts; given meat powder in the mouth, salivation occurs, given a pin prick the hand pulls back, etc.

The mind is entirely superfluous in these situations. Additionally, many reflexes will occur in an animal when there is no possibility of mental control because the head has been cut off. Clearly, a chicken is not thinking or wanting anything while it is running around the barnyard after meeting with the chopping block. Whatever non-empirical, metaphysical, and unfalsifiable claims that can be made about the mind, one thing is clear: everyone agrees it's

in the head. Remove the head and you remove the mind as a possible cause of the behavior of the rest of the body. The fact is that there are many extremely complex behaviors (such as running, turning, and balancing in a headless chicken) that are nothing more than what Descartes knew to be reflexes: stimulus in followed by what is in effect the stimulus coming back out again, but we call it a response because it is something the animals does.

Descartes was unable to account for human voluntary behavior so he perpetuated Plato's opinion about the nature of things in order to explain the cause of human voluntary behavior (thus greasing the sides of Thales' trap into which subsequent generations of scholars willfully jumped). Descartes' extension of Plato's belief was that the nonmaterial mind caused the difficult-to-predict human behavior labeled "voluntary" or "free will." For example, if a person had been sleeping, the person could awaken and say: "I think, therefore I am" (the person was not prompted to say those words). His view was that all of nature follows natural laws (stimulus in response out) except voluntary human behavior (that he thought to be not lawful). Human voluntary behavior was thought to be caused by the mind; a transcendent thing that did not follow natural laws.

It's important to note that there have never been any observations that have supported the view that voluntary behavior came from the mind. Basically, it was the time-honored tradition of when unable to understand something, claim that it is intrinsically incomprehensible or magic thus camouflaging any deficiency in your intellect (i.e., when all else fails, make the animal smart).

Further, Descartes' view was that animals were not accountable for their misdeeds because they had no voluntary behavior, and neither were humans accountable for their reflexes (e.g., their hand withdrawing from a pinprick). Humans were, however, accountable for their voluntary behavior because it was caused by the mind and the mind had free will.

Descartes' position brilliantly codified existing, well-accepted ideas (Galileo's empirical findings and Plato's opinion) into a view that was acceptable to his society, Descartes' dualistic view, is not considered a necessary solution to the problem of evil by modern theologians, but Descartes' opinion that human voluntary behavior came from the mind has grown in popularity to the point where today it is seen as "common sense" or "intuitively obvious" by people in the street. The common view is that reflex behavior "makes sense" and can therefore be scientifically studied and understood, while voluntary human behavior has no cause and cannot be subjected to scientific study.

Ironically therefore, Descartes was an important progenitor of both the best of psychology: (the scientific study of human behavior (reflexes)) and the worst of psychology: (the belief that it is helpful to invoke an inner mind as a cause of voluntary human behavior, and as a result, in principle, the behavior cannot be understood). Descartes' view of causation was dualistic. Causation in all things other than human voluntary behavior was materialistic or via the natural world. Causation of human voluntary behavior was via an internal will or mind, e.g., free will.

### 1. Conceptual Follow-Up: The Principled Implications of Descartes' View of the Cause of Behavior

- The energy of the input is reflected as the energy of the output.
- The complexity of the stimulus governs the complexity of the response.
- The same stimulus will always cause the same behavior.
- The response is necessarily immediately preceded by its controlling stimulus.
- There is not necessarily any cause of voluntary human behavior because it is caused by free will
- Voluntary human behavior cannot be scientifically studied because it is not the result of any cause, it has no specifiable relationship with anything.

## F. The Cause of Everything is Materialistic (Hobbes)

| Action Via Material World | | | | | |
|---|---|---|---|---|---|
| Non-living | Living | | | | |
| Rolling<br><br>Rocks | Swaying tree | Slithering worms | Jumping chimps | Jerking humans | Talking Humans |

*Figure 7.6 Figure showing the causal factors underlying the behavior of various things. In this case, all behavior of all things was thought to come from natural events in the natural world.*

Thomas Hobbes was a contemporary of Descartes. He more correctly advanced the history of thought as shown in Figure 7.6. He came to a more astute but less popular conclusion than Descartes. (He also lived in a country that did not kill people for disagreeing with the church and the popular culture.) Hobbs argued that voluntary human behavior occurred as the result of the pursuit of pleasure and the avoidance of pain (in the teleological sense) and was as materialistically simple as Descartes' stimulus-response reflexes.

To Hobbes, behavior was the simple reaction to the incoming stimulus. He asserted that the only difference between reflexes and voluntary behavior was that the consequence controlled voluntary behavior, whereas the antecedent controlled reflexive behavior (a truly prescient realization). He rejected Descartes' erroneous notion that voluntary human behavior was intrinsically unpredictable and occurred for "no reason." Hobbes rejected free will. Hobbes agreed with Descartes that voluntary human behavior had its origin in the mind, that animal behavior and human reflexes were innate and showed no learned adaptation, and that human voluntary behavior was adaptive and could change as the result of experience.

Note that hedonism implies a conscious internal entity that is working for a future good state while behavior analysis simply argues that behavior can best be understood in terms of the historical exposure to a reinforcement contingency (note that from a behavior analytic perspective a reinforcer does

not necessarily "feel" good). From a behavior analytic perspective, some consequences increase the rate of behavior in the future and a mind, or awareness is irrelevant, and any future goal is teleological.

It is the exposure to consequences in the past that eventually led the person to do a behavior, not that the mind innately knows to go to the things that feel good as hedonism suggests.

# II. Evolution of the Early Explanations for Behavioral Adaptation

Following the watershed separation (not necessarily correct) in the classes of behavior (physical world, materialistic causation versus mental causation) provided by Descartes and Hobbes, scholars followed one of two paths: Either the cause of behavior was a natural phenomenon (the material paradigm) or the cause had its own reality (the mental paradigm). These partitions are illustrated in Figure 7.7. Within each of these "schools," scholars either broke things into component parts (atomism or structuralism) or took them as wholes (holism or molarism). We will follow each path in turn. (Note the outline sections in parentheses.) Keep in mind, however, that the reality of the artificial mind-body or mental-physical controversy and the evolution of the study of learning stemmed from Plato's opinion and Descartes' lack of understanding, rather than reality; this dichotomy (i.e., material or physical versus mental) in questions and procedures is not based on any reliable evidence. It is not based on facts and is therefore not correct from a scientific perspective.

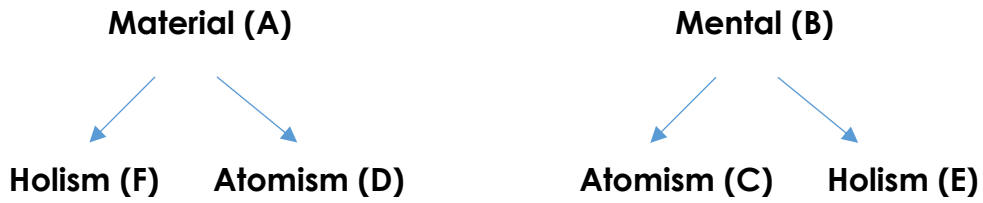


*Figure 7.7 Figure showing how the two major cases of causal factors (material and mental) can each be partitioned into atomistic or holistic explanations. The section in which they are covered is given within the parentheses.*

## A. Conceptual Overview: Materialistic (Physical or Natural World) Causation of Behavior

The spirit of this behavioral research (i.e., experiments resulting in empirical data) was the study of a natural science. Scientists studied behavior, such as stomach secretion in response to food in the stomach or heart rate as a function of exercise. This was a continuation of Galileo's paradigm changing

view that we should see the movements of a rock in terms of actions in the natural world rather than creating some internal fantasy process based on nothing more than the movements themselves. The difference in the spirit of the physical paradigm and the mental paradigm is captured in Catania's descriptions of different human behaviors. While it might be said that "I" run or "I" jump or "I" breathe (mental causation) (animal smart), it would never be said that "I" heartbeat (physical causation) (animal stupid). Metaphysically, building on that distinction, scientists in the "physical" category studied behaviors like "heartbeats," not behaviors like "running" or "jumping." Whatever is the difference in the former and latter usage is the difference between a monistic and a dualistic paradigm. (i.e., the verb class "to do" rather than the verb class "to be. "To do" verbs can have the subject "I", whereas "to be" verbs do not).

It is very important at this point to stop and realize that many behaviors, such as heartbeats **are, in fact,** obviously mindless. They occur in the total absence of a head. Even if the mind is accepted as real, it cannot be invoked in the headless case. The use of "I" in these cases is clearly silly. A plant will grow toward a lighted window; a frog's leg separated from the body will move; an isolated heart will beat faster or slower; a chicken without a head will run around; and a cat with a transected spine will scratch the place on its side that is irritated rather than a random spot. Each of these behaviors occurs when the mind has been totally ruled out by removing the brain. The important seminal realization is that some mechanism must control at least some very complex behavior in the absence of a mind. The subsequent question "whether it's productive to consider the mind as the cause of <u>any</u> <u>behavior</u> <u>whatsoever</u>, even with the head" – has been and will be covered elsewhere.

Physical behaviors were studied by scholars who came to be called scientists. The paradigmatic frame of reference for research in the area of behavior was to explain the source of the energy in the behavior as the simple reflection of the energy in the stimulus. Descartes had labeled it a reflex because the "energy in" was thought to simply reflect back. They were the behaviors as mindless as a stone rolling down a hill, or a pushed statue of a person sliding along the floor or the toy bank doffing its hat. This list included running in a headless chicken and a great many human behaviors such as pupillary contraction, knee jerks, stomach secretion, heartbeats, etc. They were involuntary behaviors and were studied by physiologists.

1. Ultimately, these investigators could believe that only a single reality existed (monists) or that two (mind and body) realities existed (dualists). By definition, however, their research interests were directed exclusively to what was physically real.
2. Rocks, animals, and humans, as far as research was concerned were the same type of existence.
3. All things could be studied directly (other than human voluntary behavior for dualists).
4. Meaningful research focused exclusively on what could be sensed,

only it had acceptable reality (empirical materialists).
5. Questions were concerned with physical reality that was appropriately studied directly via empirical investigation.
6. All laws were natural laws.
7. All things had a cause (determinists).
8. All effects were preceded by their causes.
9. Explanations were materialistic (like reaction, gravity, mass, and electricity).
10. Behavioral research was concerned with reflexive behavior. The culture accepted it as clearly having nothing to do with the mind.
11. The whole process was simply "trigger then response e.g., fire stimulates nerve, nerve releases animal spirits, the spirit flows into and fills the muscle, thus causing the muscle to contract.

### B. Conceptual Overview: Internal Mentalistic Causation of Behavior (An Assumed Cause with No Objective Support or that is Ganz Andere)

The important thing to recall while trying to conceptualize mental views is that they actually have a little person or telephone operator (a homunculus) inside the head that functions in every way like an actual complete well-informed, knowledgeable person. For example, it receives input, it thinks about the information, compares it to its memory, makes decisions, and then puts those decisions into bodily actions. For this reason, it can be conceptualized as an incorporeal little person floating around inside the brain with some kind of invisible transcendent existence. Not only that, often the little person simply chooses to do something for no reason whatsoever (free will), and therefore, in principle, its behavior cannot be predicted.

This very different paradigmatic approach was thought about and argued by philosophers for hundreds of years. This explanatory approach was no better than Thales' animisms that were put inside rocks to explain why the rocks moved or the magic invoked by primitive peoples for why people behave. The mental paradigm held that there was a mind inside the brain. This paradigm was "not-necessarily-empirical" because it was dualistic (two types of existence: "soul/mind" as well as "empirical"). It implied special laws that could only be argued by philosophers; no definitive resolution was possible. Experiments were not carried out and were not even the obvious thing to do to resolve controversy. To study empirical things that could be sensed was to miss the point; reflexes were not of the mind. Orderly results would not necessarily be expected from orderly manipulations of the mind. Inferences about the cause of behaviors based on the experiences of the subject were impossible in principle. Interestingly enough, it never occurred to these philosophers that the mind and conscious experience could be a by-product of events in the environment that directly causes behavior (as opposed to the mind or conscious experience being the source or cause of behavior).

1. Voluntary behavior came from the mind and only humans had

minds. Animals had no voluntary behavior.
2. Voluntary behavior was thought to be controlled by a non-physical entity that was not subject to physical law.
3. Voluntary behavior was thought to be totally and intrinsically unpredictable. It was absolutely impossible to predict because it is determined by free will.
4. Key words: mind, soul, thinking, consciousness, will.
5. Involuntary behavior was predictable, but not related to the mind. Its study was irrelevant to understanding the mind.
6. Cannot study behaviors of others, including speech, because it was only the physical stuff (not mind).
7. Must study one's own mind (introspection). It was the only mind open to an investigator. Mind could be studied by reflection upon itself.
    a. Note that introspection:
    assumes that the "I" (the entity that is doing the introspecting and the thing that is consciously aware) can observe the "me's" mind (the thing that decides what to do and implements free will and is being observed) when the "I" introspects about things (i.e., when the I thinks about why the me did something or what the me thought about something. That is to say that the I is aware of the real the me). However, technically it could be argued that the I is in the "reflex center" or even in a back room of a delusion not "in the loop" that actually causes the behavior of the me (Freud's view was exactly this). Introspection necessarily had to assume the I or the "watcher" was in the causal loop of the me (the mind or the thing that decides things). After all, what would be the point of introspecting if what comes out of the researcher's mouth (the I) was unrelated to the actual reasons the me did things?
    b. Assumes inputs to the mind were reliable, i.e., transmission of information from the natural world through body to the mind or the me was orderly.
    c. Assumes the mind or the me reacts to the reliable inputs in a repeatable way.
    d. All people's minds work the same, and that the differences in behavior from person to person come from somewhere else so the results of introspection research is applicable to other people.

** Note that this list of assumptions underlying the productive use of introspection was absolutely necessary for introspection to be valid but the validity of any is totally unknowable and even implausible; the entire system was built on guesses and unlikely hopes, even if there really were a mind. When you think about it, it was a ridiculous leap of faith and somewhere between laughable and sad.*

The spirit of this research was to study the presumably special aspects of

humans and the cause of their voluntary behavior, i.e., their minds. How do various inputs affect the mind and, given that some experience is relevant, how much of an impact does it have?

But this leads to the horns of a dilemma. 1) If behavior is an orderly function of aspects of the natural world, it could be better studied directly. Or, 2) If behavior were unpredictable in principle, then to study the mind for an explanation of behavior would be, in principle, unproductive

The presumed separation between human voluntary behavior and all lower animal behavior is easier to understand from a historical perspective. The early Greek culture had a strong belief that people had a spirit or psyche. Early Christian writings talked about life spirit. The Greek concept was subsequently variously mistranslated into the concepts labeled "psyche," "mind," and "soul" in English. This confusion is obvious when it is noted that very often, the way "mind" was used was identical with that same speaker's usage of "soul" with the religious context removed. For example, a pet dog had no voluntary behavior because it had no mind and it could not go to heaven because it had no soul. Note that Descartes' view required that the mind controls only those mental activities or capacities that are beyond a dog's or dolphin's ability because everything that those animals did could be done without a mind.

What follows is a historical review of the study of the mind and of the body. Recall the overview in Figure 7.7. The atomistic approaches (processes could be best understood by understanding their component parts) to the study of the mind and of the body are covered first in sections C and D because they were the most dominant themes of scholarship. This material is then followed by holistic approaches (processes could only be understood by considering causal processes as wholes).

## C. Mentalistic Atomistic Causation (All Human Behavior as the Combination of Component Acts and the Result of the Mind)

This paradigm flowed from Descartes' view of human voluntary behavior (i.e., mental causation of behavior). Under the atomistic study of mental phenomena, there are two subdivisions: behavioral repertoire developed mostly by way of experience (ontogenic); and alternatively, behavior repertoire developed mostly by way of phylogenic experiences (innate).

Each of these positions can be made more or less reasonable by a change in emphasis, for example: at the one extreme, every single scrap of knowledge via xxx, to the somewhat more moderate view that the vast majority of behavior is via xxx, to most behavior is via xxx. Probably the fairest conceptualization is that nativists believed the vast majority of behavior was innate, while the empiricists believed the vast majority of behavior was learned.

### 1. Phylogenic Experience Most Important Determinant of Human Behavior (Nativism)

From this perspective, the vast majority of knowledge (information in the

brain that the homunculus (little man or telephone operator in the brain) uses to make decisions) is innate. Knowledge is inborn or acquired through heredity. It is not entirely clear whether the following thinkers thought that the knowledge we are born with simply "popped" in there or whether they would agree with the suggestion that the species picked it up across evolution (if they knew of the notion or evolution). In either case, they believed that knowledge was not the result of ontogenic experience.

### a. Evolution of Thought

#### i. Plato (427-347 BC) [ ]

Plato believed that we are born with perfect knowledge and can know that knowledge through introspection. In fact, experience corrupts our perfect knowledge. When confronted with the questions "how do people know all the things that they know? Plato answered with the incredibly lame answer "they were born knowing it." The difference between people was that some people forgot more or reflected less accurately. Therefore, knowledge gain is to be had by thinking about things rather than by doing empirical research. This latter opinion was one of the principles that Galileo overthrew. What is surprising is how often bald-faced rationalism surfaces in modern discourses.

#### ii. Descartes (1596-1650) [ ]

Descartes believed that people are born with an innate understanding of the nature of God, infinity, and some geometrical axioms. Otherwise the mind was intrinsically unpredictable. Strictly speaking, it is not entirely clear whether Descartes would be most comfortable categorized as an atomist (because he talked about various specific ideas) or holistic. In the present framework, he is considered an atomist.

#### iii. Summary

The phylogenic-experience-most-important line of reasoning led to the belief that a child's parents were everything. As well illustrated by the fact that the ruling class (e.g., Mr. Darcy) would never consider marrying a lower-class person (e.g., Elizabeth Bennett) (Hollywood notwithstanding). How the specific language (Chinese versus English) someone spoke could be innate was an obvious problem with this sort of view.

### 2. Ontogenic Experience Most Important Determinant of Human Behavior (Empiricism) (Associationism)

From this perspective, the vast majority of knowledge was thought to be acquired through experience that was gained during the life of the individual. Recall that the cause of behavior was a little man making decisions based on

knowledge (and sometimes decisions were made for no reason whatsoever (free will)). When asked how people know so much, the empiricist would have answered "by way of their experience." The difference between people was that different people had different exposures to different things

### a. Evolution of Thought

#### i. Aristotle (384-322 BC) [ ]

Aristotle believed that knowledge was acquired by sensory experience and reasoning upon that information. Ideas experienced together tend to be remembered together through the principles of contiguity, similarity, and contrast.

#### ii. Hobbes (1588-1679) [ ]

Hobbes rejected the notion that voluntary behavior was due primarily to innate factors, in addition to rejecting the notion that it was unpredictable in principle. He argued that human voluntary behavior was as predictable as reflex behavior; and that it was not innate but rather was acquired via the pursuit of pleasure and the avoidance of pain (hedonism). Hobbes asserted that human behavior was not caused by reason. However, Hobbes did accept the view that voluntary behavior came from the mind.

He accepted Cartesian dualism and accepted that voluntary behavior was caused by the mind, but did not believe that it was free will. Organisms were thought to work to get pleasure and avoid pain (as a result morality was a false conceptualization). The mind causes body activity via hedonism, not via reason. Man, as well as animals, are machines. An organism's goal influences its activity through anticipation and that anticipation through experience. He was a resolute materialist: cause via physical motions, endeavor, or what Hull labeled fractional anticipatory responses nearly 400 years later. He was an anti-rationalist, and he was a hardcore determinist. He is one of the most under-appreciated giants in the history of science, especially psychology. Behavior analysis would have been "born" three centuries sooner if psychology used Hobbes rather than Descartes as its progenitor.

#### iii. Locke (1632-1704) [ ]

Locke believed that the contents of the mind was built up via experience and associations of small elements. The mind was passive. It was a *tabula rasa* or a blank slate. Locke was an associationist. He did not accept free will. There was a correspondence between experience (sensations) and memory (ideas). All ideas, no matter how complex, were the product of simple ideas that are the product of simple sensations.

#### iv. Summary

In general, the philosophers who argued that much of our knowledge is gained through our ontogenic interaction with the environment (they were labeled British Empiricists or British Associationists) believed that experience was very important and innate ideas were not all that important. We are born with blank slates and we become who we are as the result of experience. They agreed with the mind versus body distinction, and that introspection is the path to understand the mind. As hard as it is to believe in modern times, the necessity of actually doing experiments to validate their speculative ideas did not even occur to them (much as the field of economics is today).

### b. Principled Issues Raised by Emphasis on Ontogenic Experience as the Cause of Human Behavior

A position that argued that the mind had nothing to start with, and that the vast majority of everything came from experienced sensations, would then be obligated to argue that complex ideas were experienced sensations grouped together. The problem with accepting that all things are via experience is the task of understanding how isolated sensations are connected together in that mind to form higher-level groups like "chair."

As illustrated in Figure 7.8, the first questions would be how do the sensations get into the mind and secondly, how do they get together or become grouped into the obviously complex ideas that are in the mind.

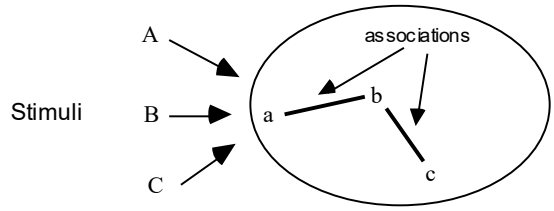


*Figure 7.8 Figure illustrating that mental atomistic explanations must account for how stimuli get into the mind from the external world and also how those individual component elements are assembled into units such as the sight, smell, and taste of apple pie are assembled into the idea of apple pie.*

In sum:

1. What is a stimulus?
   What is the nature of what gets into the mind?
   How are we to map one to the other - the real world and the mental world?
   How does a stimulus get into the mind?
   How strong does a stimulus have to be?
   In what way is it changed when it becomes a mental element (i.e., the early instantiations of the areas of sensation/perception and memory)

2. Once things get into the mind, how are they assembled into larger units?
   What is the nature of the connections?
   When are things connected?
   Why are things connected?
   For how long do the connections endure?
   What causes connections to be more or less strong?
   (i.e., the early instantiations of the area of association or "learning" and cognition and behavior analysis)

### i. Translation of Material World to Mental World: Sensation and Perception

To the people who believed the importance of ontogenic experience, it is important to study stimuli and how they get into the mind (see Figure 7.9); how do sensory impulses pass from the physical world to the mental world and how are they changed when they get in there.

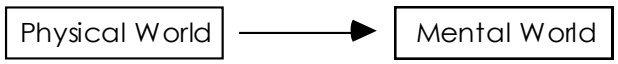


*Figure 7.9 A simple visual instantiation of the issue that the physical world must somehow get into the mental world.*

Recall that the mainstream were philosophers that were pre-Galilean (in spirit if not in time). The functional relationships that the philosophers were after were typically intended to reveal how the inner mind worked rather than being targeted at what inputs to the person caused what behaviors the person did (the functional properties of the person's behavior with respect to the events in the natural world which was how Galileo had conceptualized the movement of rocks).

Rather these mainstream philosophers were animist like Thales (they made up things inside the object of study to account for the behavior of that thing). An excellent illustration is provided by the work of Weber and Fechner. Weber (a Galilean) ("a behaviorist") documented the relationship between stimulus intensity and behavior. Fechner (a Thalean or a "cognitivist") took that factual data that specified what had happened, and used it to estimate how the mind worked.

#### (1) Stimulus Detection

A natural question concerns the smallest stimulus that can be detected. Exactly what are the capacities of the sensory system?

### (a) Weber (1795-1878) [ ]

Weber proposed that there is an orderly relationship between overall physical intensity and the smallest possible detectable increment in intensity. One candle added to ten candles was just noticeable but ten candles added to 100 candles were required to be noticed. An increase in overall intensity produces an increase in the just-noticeable difference magnitude. That is, a difference that is just noticeable i.e., a just noticeable difference or jnd is proportional to the stimulus intensity. Weber's law was strictly a functional relationship; in that sense, Weber was a behaviorist. He did not talk about how the mind caused behavior, but rather he was entirely focused on how changes in behavior were a function of changes in the environment. Weber's law is $\Delta I / I = K$.

To review, if we could just detect when 1 candle was added to 10; then we could just detect when 10 were added to 100, and 100 were added to 1000. We could not detect an increase if only 9 are added to 100, or 99 were added to 1000. In this case, the JND for candlelight would be 1/10 = K, K = 1/10, or K = 10%.

### ii. Construction of Complex Mental World: Associationism

The second important area of investigation to people who were after the discovery of mentalistic atomistic causation as the result of ontogenic experience, was how complex ideas and thoughts came to be (see Figure 7.10). The solution was that they were built from the association or combination of simpler building blocks, much as all the knowledge in all the books in the library is the combination of simpler building blocks (i.e., a few hundred thousand vocabulary words which were in turn made up of only 26 letters).

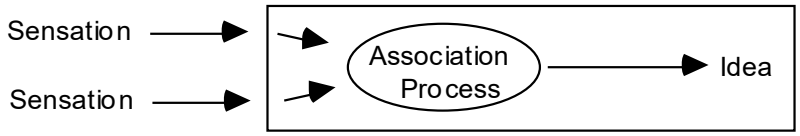


*Figure 7.10 A simple figure instantiating the issue that some association process is necessary to combine isolated sensations into ideas.*

#### (1) A "Perception" as a Combination of More Basic Elements

In the context of a paradigm that asserted that a whole was made up of more basic component parts, the proponents of this paradigm made a hypothesis concerning how the nervous system worked. The result was the discovery that different neural paths are used for different aspects of a stimulus (such as red, green, and blue paths) thus adding substantial credence to an atomistic approach.

### (a) Evolution of Thought

#### (i) Müller (1801-1858) [ ]

Sensation is not so much the actual stimulus (e.g., photons of red light directly affecting the mind) but rather which nerve is stimulated. After all, a red light does not appear as a red spot in the brain when we look at a red light. Complex stimuli are broken up into various properties or aspects, each carried by a specific nerve. Once an event passes the original sensory receptor (such as the rods and cones), the stimulus (the red light) is no longer there. It is only electrochemical activity "encoding" various properties of what you saw. There are no "stimulus objects" in the brain.

#### (ii) Helmholtz (1821-1894) [ ]

Helmholtz drew heavily on associationism and argued that the experience of something was a few actual current stimuli but mostly the result of associations from past experience (i.e., what is frequently labeled "perception" as opposed to "sensation"). That is to say the current mental experience is the present stimulus input as modified by, mixed with, or with respect to prior experience.

### (2) A "Cognition" as a Combination of More Basic Elements

Complex ideas were seen as combinations of simpler ideas, and meaning was the result of the association of a word with an event or many events through contiguity. An individual hears a word and associates it with concurrent sense data e.g., hear apple pie and see and taste apple pie. In particular, proponents of this paradigm were in search of how principles of contiguity act in specific instances to produce complex experiences, and, in fact, our entire mental life. All mental life was seen as based on the association of simple sensations.

Rather than a widespread focus on the functional relationships causing behaviors to be what they were, the focus was on trying to understand the inner thing that caused the person to behave as they did. Introspection research was the study of the components in the mind making up thought, personality, and humanity rather than the environmental events precipitating the emergence of the association itself or even the environmental events causing the expression of the thoughts. It was not the probability of a behavior as a function of a stimulus. Introspection was used to get at the mind in lieu of getting at the environment that put those things into the mind. The task of introspection was therefore misguided. Typically, introspection and verbal reports were used to break overall sensations up into components parts and analyze complex mental experiences into mental elements, from that it was believed that the general laws with which elements were associated could be discovered. The thing to do was to have trained observers analyze experience into constituent elements.

### (a) Evolution of Thought

#### (i) Aristotle (350 BC) [ ]

The "mental glue" to cause the assembly of basic elements into complex ideas was provided by principles originally proposed by Aristotle. We remember things together when:

1. they are similar
2. they contrast
3. they are contiguous

Obviously anything could be either similar or contrasting, so the principle made many false alarm predictions. For Aristotle, these principals accounted for the fact that one thought leads to another and that thoughts are not random. It was a relatively small step from one thought leading to another as Aristotle had proposed, to one idea combining with another idea to produce a more complex idea.

#### (ii) James Mill (1723-1836) [1829]

What we know of the world is through the senses. His view was that ideas were formed as a result of mental mixtures. All sensations related to chair become the meaning of "chair." Elements of the world are sensations and objects are combinations of these sensations. An example would be that each instant of a symphony is the combination of the simple mixture of different instruments.

#### (iii) Brown (1778-1820) [1820]

Brown proposed the Laws of Association. Which stated that which elements would become associations are determined by properties such as duration of contiguity, frequency of pairing, and recency (among others).

#### (iv) John Stuart Mill (1806-1873) [ ]

John Stuart Mill argued that ideas were developed as a result of mental chemistry. All sensations may combine to produce something new, not mixture like salt and pepper, but rather like oxygen and hydrogen to produce water with emergent property. An example would be that everything in the universe is the combination of only 117 elements.

### c. Subsequent Philosophical and Experimental Developments Concerning the Ontogenic Causation of Human Behavior

#### i. Spencer (1820-1903) [1855]

Spencer led a paradigm revolution with his view that the mind was **created** by our experiences. Spencer agreed with Hobbes that evolution had linked pleasure and pain with survival and that the species survived as the result of

that linkage. Spencer, like Hobbes, also explained behavior by way of an internal entity: the mind. But Spencer differed from Hobbes in that he argued that pleasure and pain guide behavior via **what we learn to be** not simply what the mind knew to do from birth in order to obtain pleasure and avoid pain, or what the mind wanted. The giant step in the advancement of the conceptualization of adaptation was the difference between an immediate-term adaptation reaction to a stimulus (Hobbes) and Spencer's short time scale adaptation, or what is sometimes called learning. **Spencer's focus was on how the mind came to be what it was, not simply what choices the pre-existing or pre-formed mind made.** That realization qualifies him to stand with Galileo and Hobbes as a real giant in the progress of psychology. Spencer's realization was that we **are what we learn** not simply some innate mind that makes choices. Spencer understood that there was a second level of the adaptation of behavior to a stimulus: not simply a reaction but what has come to be known as short time scale adaptation.

The difference in his conceptualization from what went before is substantive. From Hobbs' perspective, there was an inner "operator" directing the body toward pleasure and away from pain (hedonism). To Hobbes the inner little man always knew what to do given an input. From Spencer's perspective, the inner little man or homunculus was built or learned everything that made it what it was, based on the input. The mind learned to approach things associated with pleasure and learned to avoid things associated with pain (reinforced operants). This was the first significant paradigmatic advance since Descartes and Hobbes. With the exception of his mentalism, Spencer's paradigm (learning) linked with Hobbes' materialism is the core of behavior analysis.

### ii. Ebbinghaus (1850-1909) [1885]

Ebbinghaus also led a revolutionary change in paradigms. He started the sea change to research-defined truth. He had a paradigm changing realization: people should collect empirical evidence for what they asserted. According to association theory, a person was thought to associate an element with all other elements. The closer the elements were the more they were associated. Ebbinghaus was interested in the deterministic impact of frequency and recency of association. Ebbinghaus did the first formal experiment on learning. He was a pioneer in the use of empirical data and the method of differences to construct explanations. He was an early behaviorist. He characterized the functions that related inputs to outputs. His research was externalistic. He did not focus on internal causes; rather he documented how a behavior varied with types of experience. He studied the quantitative relations implied by the generally accepted machinery causing associations (Aristotle and later Brown). He was not satisfied to know that more contiguity produced more learning but rather wanted to know exactly how much pairing produced how much association. It is amazing that it had been 1500 years before it had occurred to someone to empirically test the fundamental principles of associationism (note

that his work occurred in the era of straw hats and barbershop quartets not so long ago

### D. Materialistic Atomistic Causation (All Behavior Including Human as the Combination of Acts and the Result of the Environment)

This second major paradigmatic approach (physical atomism rather than mental atomism) did not focus its efforts studying something that may or may not be true (i.e., the mind). Rather, this research focused on what was absolutely known to be real. What inputs caused what outputs? If intellectuals of this period were the "three little pigs," these scholars decided to build a house of brick rather than sticks or straw. It was much slower to construct their kind of knowledge but much more focused on reliable events (reality). It also left an enduring knowledge base that is still basically correct rather than opinions that have been scattered in the winds of time.

Oddly enough, Descartes was also the progenitor of this paradigmatic approach. It was based on his view of human and lower animal reflex behavior. He had asserted that much human behavior and all animal behavior was simply the reflections of events in the environment back to the muscles. He labeled the fluid that flowed around in the body carrying out this mechanical transfer of energy "animal spirits." The questions that the subsequent researchers asked can be seen as verifying, refuting, or documenting the machinery that Descartes envisioned. Descartes had speculated that reflexive behavior was from the energy of the stimulus traveling up the nerve and reflecting back to the muscle along the same pathway. Metaphorically, the harder a coin is rolled into the toy, the harder and faster the hat is doffed. Animal spirits were the vehicle and they acted by swelling the muscle through their hydraulic force. Reflexes were thought to be innate and unchangeable. The paradigmatic research following Descartes revealed the actual factors affecting "mindless" things like withdrawal from fire and the heart beating. Further, this mechanistic explanatory framework was also used by some for complex voluntary behaviors ("breathing" or "jumping").

It is important to note that this research had a clear internalistic orientation. There was a strong interest in the internalistic path taken by the "energy in" in its travel through the body to become the "energy out." The task could be likened to trying to trace the travels of a penny through a mechanical bank that doffs its hat when a coin is put in. Note that a behavior analyst would first vary where the coin was placed or vary the position of various parts of the toy to determine the entire repertoire of the toy and what made it do what, rather than to first try to trace the internal path of one single possibility. (Recall the Smart Phone and the egg pattern testing).

### 1. Evolution of Thought

#### a. Swammerdam (1637-1680) [ ]

Swammerdam demonstrated that neural conduction was not animal spirits flowing from the mind or the pineal gland. Isolated muscle would work when the nerve was mechanically stimulated. Additionally, a heart beats outside a body. Either organs do not need a mind or each organ has its own mind which lives after a person's death. The obvious parsimonious explanation was that the mind is unnecessary for behavior to occur.

#### b. Sechenov (1829-1905) [ ]

Sechenov was another one of the true giants in the history of psychology. Sechenov worked with spinal preparations and turned general research interest to behavior away from the study of ideas. Sechenov was a strong spokesman for rigorous, reliable research and theorizing, even at the expense of the pace. He argued that the acquisition of knowledge about behavior should start with the simple (analysis) and that there was a clear difference between hypothesis and fact.

Much of Sechenov's work was within an internalistic perspective. Sechenov conceptualized the notion of excitation and inhibition. He removed a portion of the brain and found reflexes faster or stronger. That indicated that the brain exerted inhibitory control, and led him to argue that inhibition was an important factor in controlling behavior.

Sechenov also pointed out that stimuli could function as triggers of behavioral processes rather than simply being reflected back out as responses. Additionally, he argued that thought could be a by-product or result of external causes rather than thought being the originating cause of behavior.

The impact of Sechenov's conceptualization of the causal factors underlying behavior were far reaching. He was able to account for three of the four failures in Descartes' simplistic reflex explanation of behavior(see below).

##### i. Conceptual Coordination: Sechenov's Resolution of Three of the Four Failures in Descartes' Explanation of Behavior

###### (1) Energy Out is not Equal to Energy In

A problem with prior views of reflexes was that actual energy in the stimulus did not always equal energy in the behavioral output. Sechenov's conceptualization of stimuli as triggers rather than energy inputs to the reflex solved the inconsistency. For example, an electric toy bank is activated by the simple presence of the coin rather than activated by the force or weight of the entering coin.

###### (2) Complexity Out is not Equal to Complexity In

Sechenov's trigger conceptualization also handled the problem that complex behaviors did not necessarily need an equally complex stimulus. The

complexity could be built into the underlying stimulus response mechanism and would only need a simple trigger for the complex behavior to occur.

#### (3) The Absence of a Causal Stimulus for Voluntary Behavior

A third problem which stumped Descartes had been that voluntary behavior has no clear eliciting stimulus. The behavior seemingly arises from within the person. To Sechenov, it was obvious that voluntary behaviors were actually triggered by very subtle stimuli in the environment of which we are not necessarily aware (such as a bit of dust causing a powerful sneeze). A reflex then became a complex machine-like input/output process that could be modified by unnoticed and simple signals from the environment.

#### (4) The Behavioral Result of a Stimulus Can Change

One problem remained unsolved with Sechenov's behaving machine: how could behavior be different to the same stimulus over time. For example, if a pigeon pecked the left key when the lights were green, how could it ever come to peck the right key when the lights were green. How could behavior occur which was not programmed in by evolution? In Sechenov's system, animals must remain fixed. He had no way to deal with short time scale adaptation or learning. Clearly, humans were modifiable via experience.

### c. Mach (1838-1916) [ ]

The meaning of a thing is the sum total of all of its functional relationships. The sum total of all an entity's functional relationships was a more meaningful definition of a thing than the sum total of all an entity's physical properties. The definition of a Smart phone is all the functional relationships pertaining to it, rather than all of its simple physical properties.

### d. Sherrington (1857-1952) [1866]

Sherrington showed how simple reflexes were integrated by the spinal cord into simple adaptive behaviors. Sherrington worked on spinal or decerebrate animals. These preparations behave in only reflexive ways and cannot learn; they were perfect Sechenov machines. Reflexes show no "ontogenically" acquired adaptiveness (short time scale adaptation) but show remarkable phylogenic adaptiveness (immediate-term adaptation via evolution or long-term adaptation). Decerebrate animals walk, run, scratch, and withdraw from a thorn, shake their head when wet, swallow milk and reject acid. But, after a delay, the behavior returns to a "base" state. Acquired functional relationships are completely reversible. There is no evidence of learning (all were immediate-term adaptations). Sherrington postulated the "final common pathway" approach to the laws of reflexes.

This set the stage for Pavlov (discussed in the next chapter) taking

psychology one step further by discovering how the brain did precisely the same type of "integration" at a higher level than Sherrington's spinal cord integration so that all behavior could be understood. (Pavlov also demonstrated short time scale adaptation which answered the fourth failure of Descartes' principles of behavior.)

### E. Mentalistic Holistic Causation (Behavior Only as a Whole and is the Result of the Mind)

Some people rejected analysis or atomism as a meaningful way to study mental phenomena. The holistic mentalists felt that phenomena may have emergent properties beyond their component parts and must be seen as wholes

### F. Materialistic Holistic Causation (Behavior Only as a Whole and is the Result of the Environment)

Packages of stimuli (combination of various senses or various consecutive stimuli) can control packages of behavior (going to the store, getting a PhD).

### G. Conceptual Follow-Up: Breadth of Analysis

The holism/atomism or molarism/molecularism controversy may be more apparent than real. From a functional perspective, understanding must be accomplished at whatever grouping size shows order. It is the ability to generalize and predict to all levels of analysis that is the goal.

### H. Summary

#### 1. Pre-Darwin Status of Theorizing: Mental Paradigm

At this point in the history of the materialistic paradigm among the mental atomists, everything about a person (a person's essence, their personality, their hopes, dreams, and thoughts) was believed to be constructed from a restricted set of sensations via contiguity and experienced pleasure and pain. The eventual impact of this perspective was enormous. The totality of a person was the program semi-permanently installed by the environment through the association of experienced stimuli. Learning was how a person came to be whom they were; and learning was how a person would become who they wanted to be.

The only weakness of the paradigm was that mainstream research at this time was typically internalistic introspection and had little to do with how things in the mind came to be. It was rarely targeted on the environmental details causing the association (as Ebbinghaus had done). The prevailing view was that the component parts of the internal cognition must be discovered just as the red, green, and blue components of color had been discovered. The discovery of the indivisible parts or atoms of cognitions or the "analysis" of the

mind was what introspection was all about. For example, the fundamental processes such as “activation,” expectation,” and “positivity” were advanced as the core of a person’s thoughts.

### 2. Pre-Darwin Status of Theorizing: Material Paradigm

At this point in the history of the materialistic paradigm, extremely complex behaviors were well understood within a coherent framework that did not invoke a dualistic, non-empirical explanation. Additionally, these behaviors were seen as the natural result of the grouping of atomistic processes.

Unfortunately, there was a strong bias toward internalistic explanatory mechanisms that often had an insufficient focus on the systematic experimental evidence demonstrating an actual relationship between the putative environmental cause and the obtained behavior.

# CHAPTER 8

# Modern Evolution of the Explanatory Framework for the Experimental Analysis of Behavior

## I. Conceptual Precursor: Darwin's Impact on the Life Sciences

A. Fundamentally different paths in the initial post Darwin evolution of the explanation for short time scale behavioral adaptation

## II. Search for a Mind as a Cause of Behavioral Adaptation Across All Species

A. Comparativists
   1. Romanes
   2. Morgan
      a. Conceptual context: historical note re: parsimony
         i. Ockham's Razor
         ii. Morgan's canon
         iii. Wittgenstein's recognition
         iv. Palya's quip

B. Functionalists

## III. Schematic of Modern Materialistic Conceptualizations of Short Time Scale Behavioral Adaptation or "Learning"

## IV. Modern General Process Learning Theories

A. Pavlov
B. Thorndike
C. Watson
D. Hull
E. Skinner
   1. Conceptual distinction: radical behaviorism versus simple behaviorism (Palya's version of the distinction)
      a. Conceptual follow-up: best practice versus common practice
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F. Rescorla ( ) / Wagner ( ) (1972)
G. The future of learning (short time scale adaptation) theories

# CHAPTER 8

# Modern Evolution of the Explanatory Framework for the Experimental Analysis of Behavior

## I. Conceptual Precursor: Darwin's Impact on the Life Sciences

Charles Darwin inspired a paradigmatic revolution just as Descartes had done. After Darwin, nature and the behavior of life forms were no longer seen in the same way. This new paradigm was based on what in retrospect were simple and obvious observations.

It had long been well accepted that life forms were similar, and that there seemed to be continuity from one to the other. The fact that evolution occurred was generally accepted for centuries before Darwin. Very many facts that were known and accepted supported it. It was how that continuity could have happened that was the mystery.

Darwin's contribution was actually not that life forms evolve but rather the realization that evolution could occur by natural selection rather than divine selection. What he enunciated was the mechanism whereby evolution could happen. What he pointed out was that if there were: 1) variations within a species, 2) selection by reproductive advantage of some of those varieties, and 3) non-regressive replication, then eventually there would be exactly the continuity and diversity we observe across life forms in the total absence of any magic or divine control. In sum, if natural variation and natural selection; then the variety (and the harmony!) of the many species would be accounted for. The modern arguments against evolution come from very small but strident religious sects primarily in rural America and are not based in evidence. It is the same argument that insisted that the earth was flat, that the sun orbits the earth, and that the digit zero was the work of Satan (and that shamelessly justified the burning alive of anyone who disagreed).

Variation and selection provided a natural explanation for the similarity and diversity in nature and the amazing adaptiveness in living things. How this could easily occur is illustrated by example: one pair of houseflies in April could produce 191,010,000,000,000,000,000 flies by August. Only a few flies survive. In fact if the number of flies on earth is remaining relatively constant, then the best guess is that only two flies survive out of all the potential offspring of a pair of flies. Because there are many random variations between offspring, and variations

between parents and offspring, this "cut" ratio is capable of selecting individuals very different than the parents if that change is called for by any change in the environment. The surviving flies are the best out of billions upon billions for the encountered environment, because those that were best suited to the conditions would be the most likely to reproduce. As a result, the best guess is that flies are pretty much capable of maintaining themselves by natural selection at the approximate ideal for an environmental niche even if the environment dramatically changes.

Just how small of an advantage is necessary to produce a species that comes to predominant can be seen by a thought experiment. Imagine two spaceships, one traveling at 10 mph and the other at 11 mph. After a million years, one will be 8,760,000,000 miles ahead of the other. As a second example, imagine that you had a herd of 1000 pigs and you could select the two most extreme (largest, smallest, fattest, longest, etc.) and move them to some new farm. You let them breed and build a herd to 1000 again. Suppose you again choose the two most extreme along that same dimension and move them to a new farm. Suppose you repeated the whole process 1 million times. By the time you got to the millionth generation, the animals would be nothing like the original species. You could have what were originally pigs, flying if that was the dimension that you selected for. This pig example is artificial selection rather than natural selection. The only thing Darwin said was that something similar could happen with natural selection based on naturally occurring contingencies. Darwin realized the obvious: 1) variation; 2) differential reproductive success; and 3) the non-regressive replication of the best suited, can produce evolutionary change. Note that adaptation occurs to experienced conditions not toward some future goal. It is not that nature has intentionality or purpose like the farmer but rather that some life forms are more adaptive to their environment than others. Rather than becoming more what a long-lived farmer wants, the life form would conform to the requirements of nature, and the life form would adjust to changes in the experienced environment.

There were important implications to evolution: 1) continuity in species, and therefore, continuity between man and other animals; 2) the consequence of any behavior with respect to evolution (long-term adaptability) is a critical element in the understanding of behavior; 3) because evolution proceeds in small steps then an atomistic analysis should be maximally productive; 4) it is unlikely that the brain structures involved in speech were around when much of our brain and behavior evolved. As a result, the mind is not an essential element in the explanation of behavior. In point of fact, the idea of a mind is a impediment to understanding behavior, and 5) things have a natural materialistic cause and magic need not be invoked.

After Darwin, virtually all areas of psychology and biology became sciences rather than philosophies (see Figure 8.1). It became obvious that humans were not wholly and entirely different than all other life forms. If the adaptability of animals does not require a mind as a cause, and man and animals are continuous, then man's adaptability can be best understood and explained without recourse to a totally different kind of existence outside the natural world (mind). With the loss

of the need for a mind, a sea change in science began. After Darwin, it became increasingly difficult to consider the wild ravings of a drug-crazed lunatic, the speculations of a philosopher, and the empirical proof of a researcher as equivalently believable. Materialistic causation accounts for the most variance, and as a result science inexorably evolved to an empirical materialistic epistemology. Simply put, it provides the best answer.

| **Action Via Material World** | | | | | |
|---|---|---|---|---|---|
| **Material World** | | | | | |
| Non-living | Living | | | | |
| Rolling Rocks | Swaying trees | Slithering worms | Jumping chimps | Jerking humans | Talking humans |

*Figure 8.1 Figure showing the causal factors underlying the behavior of all things. In this case, all things were of the same type (monism) and were thought to behave because of natural events in the natural world (materialism).*

### A. Fundamentally Different Paths in the Initial Post Darwin Evolution of the Explanation for Short Time Scale Behavioral Adaptation

The worldviews for researchers concerned with understanding the "mind" and "body" had to change in light of the demonstrated commonality between man and other animals.

One group initially perseverated in believing in the mind but some window dressing was added to make it seem less non-natural and not the only causal factor underlying voluntary behavior in people. This lead them to the mind also becoming the causal factor in the behavior of lower animals. The credibility of this view eroded.

For the other group, a natural or materialistic explanation for human voluntary behavior, as well as lower animals, became essential.

These two views are schematized in Figure 8.2. The initial split in scholarly work in the study of behavior was as is presented in the two boxes below (followed by the outline sections):

| | |
|---|---|
| If animals and man were basically the same<br>then<br>If animals did not need a mind, then humans did not need a mind. (III) | If animals and man were basically the same<br>then<br>If there was a mind in man, then there is a mind in all animals. (II) |

*Figure 8.2 Figure illustrating the two logical implications with respect to "the mind" of the fact that animals were continuous from the most basic lifeform to man.*

Adding to the structure we presented earlier, we have figure 8.3.

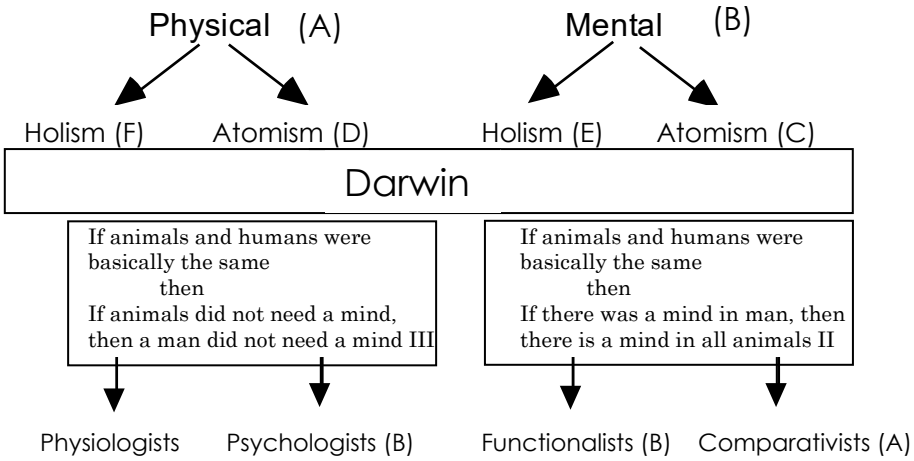



*Figure 8.3 Schematic illustrating how Darwinism and the realization that all life forms were continuous changed the earlier paradigmatic approaches used to explain behavior. One resulting approach extended the human mind into lower species. The other resulting approach realized that if minds were unnecessary for lower organisms, they were unnecessary for humans.*

Note that with Darwin came an entirely new conceptual tree. The prior organizational structure did result in some conceptual inertia for individual researchers but eventually it was washed away by the evolutionary mindset.

# II. Search for a Mind as a Cause of Behavioral Adaptation Across All Species

After Darwin, researchers who had emerged from the tradition emphasizing the mind (recall the discussion in II A and II B) generally came to focus on one of two issues. They were labeled comparativists and functionalists. It was not so much that they believed in an entity unconstrained by the laws of nature, but rather they had a conceptualization of the cause of behavior as a "thinking, decision-making system in the brain. Cognitive psychology emerged from this tradition.

### A. Comparativists

Evolution obviously shapes the body through variation and selection; evolution is just as likely to shape behavior (i.e., some behaviors provide relative reproductive success). Comparativists studied attributes of animal minds initially to evaluate Darwin (via finding or not finding continuity in mental process across species) and eventually studied those attributes in their own right.

They studied how the mind was shaped by selective pressure in order to

understand the evolutionary trend that had as its current end, man. The researchers studied the capacities of animals. The approach was to study the expression of the homologous (i.e., "same") behavior in at least two different species (the difference in the behavior was caused by the difference in the species) to study evolutionary forces that controlled the development of the mind (thus the title comparativists). These researchers studied how different animals evolved different behaviors to adapt to different niches. Lions behave differently than antelopes and the reason is the natural selection of predator and prey optimizations. It is interesting to note that it is the lions that make the antelopes elegantly fast and graceful and reciprocally the antelopes that make the lions magnificently powerful and deadly.

### 1. Romanes (1848-1894) [1882]

Romanes focused on the study of behavior rather than biology. He carried out laboratory research, and searched for particular determinants of behavior. Romanes was one of the first to make the now obvious point that lower animals benefit from ontogenic experience. It is very sobering to realize that it wasn't until well after the Civil War before it was believed a dog could learn a trick as the result of its ontogenic experience!

Romanes pointed out that adaptive behavior could be as a result of exposure to the environment rather than simply inborn instincts. His impact was limited by what from a modern perspective were quite foolish errors. He collected anecdotal evidence with anecdotal explanations, and he asserted that we could infer that animals have the same conscious state humans have if they were doing the same act that humans do. This error and its resulting massive waste of research effort is a perfect example of the reason behavior analysts build their theories on the bricks of facts rather than guesses about the straws of internalisms.

Additionally, Romanes' view was that because animals acquired adaptive behavior as the result of ontogenic experience, animals could be said to have minds or intelligence.

Romanes' view was one way to implement Darwin's realization that lower animals and man were continuous.

### 2. Morgan (1852-1936) [1894]

His famous canon in response to Romanes' excesses (actually, Morgan's canon was Ockham's razor) stated that adaptiveness in animals does not necessarily imply insight or self-awareness on the part of the animal. It might just as well be the result of simple associations. Behavior could be as mindless as a headless cat scratching an irritation on its side.

His canon was leveled at the Romanes' style of explanation, which postulated cognitive skills whenever an explanation for a complex behavior was necessary. The dictum "smart animals prove the experimenter stupid; stupid animals prove the experimenter smart" can be seen as a more pitiless version of Morgan's canon.

#### a. Conceptual Context: Historical Note re parsimony

The principle of parsimony has a long history.

##### i. Ockham's Razor

"Entities must not be multiplied beyond necessity."

##### ii. Morgan's Canon

"In no case is an animal's activity to be interpreted in terms of higher psychological processes if it can be fairly interpreted in terms of processes that stand lower in the scale of psychology evolution and developments."

##### iii. Wittgenstein's Recognition

"Where (or of what) one cannot speak, one must pass over in silence."

##### iv. Palya's Quip

Smart animals prove the experimenter stupid. Stupid animals prove the experimenter smart.

### B. Functionalists

The functionalists also accepted that animal minds are continuous with human minds. Their view was that the study of the human mind is easier if carried out on simpler systems such as lower animals (analysis). Functionalists had a clear experimental approach to coming to know how things worked and a bias toward environmentalism and associationism.

Originally, they were focused on what the mind was for (from an evolutionary perspective), rather than the structure or processes of the mind. Later there was a shift to an interest in how the mind came to be what it was. That is to say they realized the importance of the origin of the ideas in the mind and how the mind came to make the decisions it did (following Spencer's brilliant realization that the environment created the mind).

The analysis of the problem-solving capacity in animals soon gave way to systematic experimental analysis of the broader problem of how animals learn to adjust to their environment. The interest became one of coming to understand the nature of adaptation to problems posed by nature and the nature of associative learning rather than the study of the continuity between man and animals to evaluate Darwin.

These researchers approached behavior from Spencer's perspective and that came to be the perspective of psychology in general. Rather than to study how different animals behaved differently, functionalists were interested in the commonalities of adaptation to the environment across species and how the fundamental machinery that caused it worked. This would reveal the

fundamental determinants of adaptation itself. These were the important sea changes that led to modern psychology and the experimental analysis of behavior.

The subsequent shift in the focus of functionalistic research to the assessment of the atomistic components of associative learning drove the experimental apparatus to evolve from the self-report of conscious experience, to the factors that controlled the complete sequence of turns in a Hampton Court maze as a unitary problem, to the factors that governed a correct turn at a single choice point T-maze, to the factors controlling a straight run in a straight runway, to the factors controlling the movement of one leg (a lever press in a "Skinner" box). The evolution of research was classic analysis, to simplify everything down to a manageable question, the answer to which could be used to build even the most complex behavioral repertoire. The path through even the most complex Hampton Court maze is nothing more than many leg movements each under the control of its stimulus. The search was on for proving the animal could be perfectly predictable given knowledge of its environment and history (i.e., was "stupid") i.e., the search was on for the environmental cause of behavioral adaptation. The standard procedure to evaluate an organism's adaptation became the documentation of how behavior adjusted and became asymptotic as a function of experience instantiated as a series of presentations of a learning task or "trials."

# III. Schematic of Modern Materialistic Conceptualizations of Short Time Scale Behavioral Adaptation or "Learning"

With the evolution of the epistemology of science came a repartitioning of the various areas of research that had begun with Descartes. Figure 8.4 illustrates that the original split between physical and mental explanations for behavior evolved into a split between externalistic and internalistic explanatory systems for short time scale adaptation or "learning."

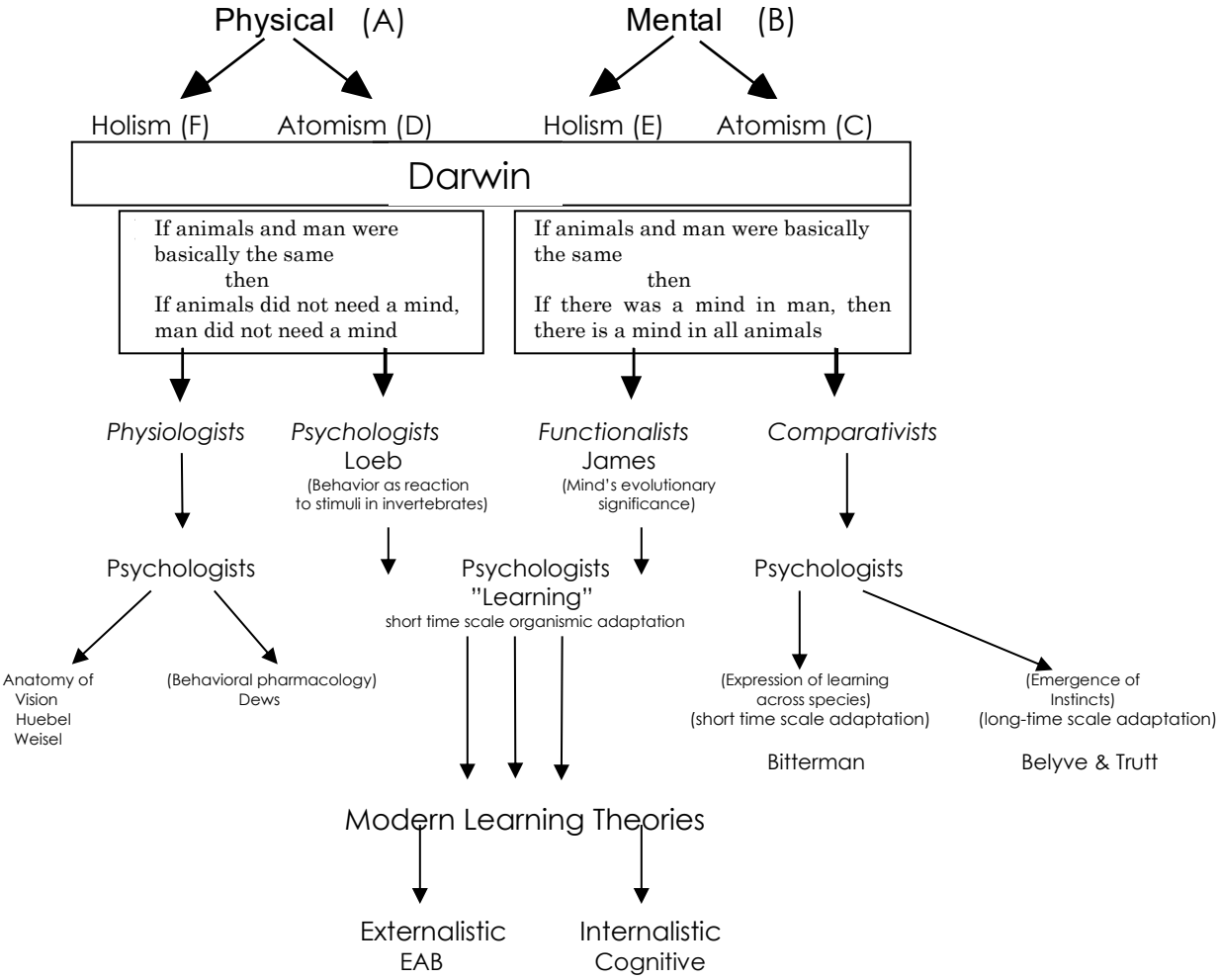



*Figure 8.4 A schematic of the evolution of the major paradigmatic approaches to the explanation of behavior with an emphasis on the evolution of EAB and its context from Darwin to the present.*

# IV. Modern General Process Learning Theories

This section of this chapter is an adapted summary of some of Robert Bolles' text on general process learning theories (the Skinner material is a more substantial departure from Bolles). Refer to his text for the original and more detailed treatment of the following material. You really should read his or some other text on modern theories of learning. It is not suggested that Bolles would have agreed with everything in this section.

In general, modern learning theories are all in search of a materialistic explanation for behavioral adaptation across all higher species.

To preview the challenge: dogs reacted to their caretaker after they were fed for a few days and cats did what was necessary to escape from a puzzle box after a bit of experience with the task. One answer could be that space aliens were controlling the animals. A second answer could be the animals had a human mind in their brain and it understood what to do exactly as well and in exactly the same way as the experimenter.

The challenge was to come up with a materialistic (i.e., scientific) cause rather than simple minded (i.e., foolish) ones.( i.e. how to make the animal's behavior the simple inevitable result of the contingencies or "stupid") Pavlov and Thorndike earned an honored place in the annals of science by staying focused on finding a reasonable explanation for short time scale organismic adaptation rather than useless tautologies or silly appeals to space aliens and the like. Their struggle of how to conceptualize the cause of short time scale organismic adaptation by using only real world provable explanations continues to this day.

### A. Pavlov (1849-1936) [1902]

Before Pavlov, Sherrington had shown how the spinal cord had integrated spinal reflexes; Pavlov had wanted to extend this approach by showing that the higher parts of the nervous system (i.e., the cortex) provided the mechanism for integrating the higher behaviors. Pavlov was primarily interested in how the nervous system integrated behavior and his work with the digestive system was only to advance that end. The results of his research led to his shift from stomach secretions indexing neural integration to salivary conditioning procedures as indexing the neural integration process.

The paradigmatic framework within which Pavlov began his research was Sechenov's modification of Descartes' explanation for behavior. Descartes explanation for the behavior of organisms was straightforward. Behavior to a stimulus was a simple reflection of the stimulus energy back out as response energy. The problem with this simplistic view was that there could be strong behavior in the absence of any strong stimulus. Sechenov had solved this conceptual problem by pointing out that a very faint stimulus could trigger a strong behavior if the stimulus functioned to release the behavior rather than to provide energy for it. Sechenov's realization had also accounted for the illusion that behavior was free will and had no environmental cause.

Recall that the belief at that time was that all behaviors of all animals except humans were inborn. As a result, if a light flash caused a dog's eye to blink then it could not at some later time cause the dog to turn in circles. The functional relationship must be fixed if it is inborn.

Into this context, Pavlov's work arrived. Pavlov found the changes in his dog's behavior with increasing experience as illustrated below in Figure 8.5.

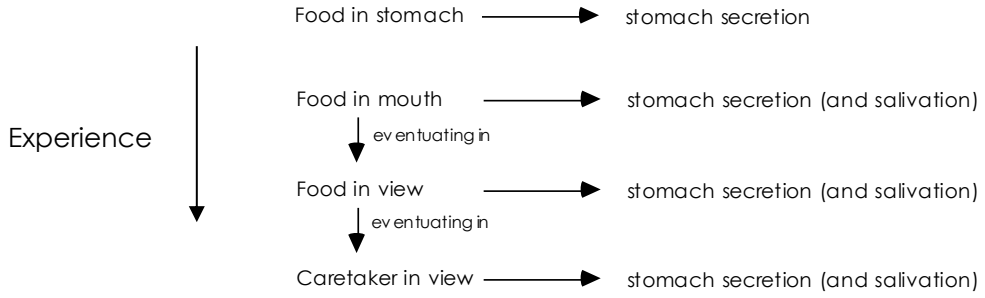



*Figure 8.5 Illustration of the evolution of stimulus-response relationships observed by Pavlov and the paradigm changing "caretaker-secretion" one. This revolution producing finding revealed ontogenic learning on the part of an organism other than humans.*

It was not plausible that the last reflex (caretaker producing-stomach secretion and salivation) was inborn. Pavlov realized that each animal possesses: 1) a fixed innate set of relatively simple reflexes such as food in mouth produces stomach secretion and salivation, which occurred unconditionally and, 2) that animals can come to have a set of acquired reflexes by way of their interaction with the environment. The behaviors were conditional on the specific experiences of the dog.

The fact that reflexes could be acquired solved what was insurmountable to Descartes. Animals could learn to behave differently to a stimulus. This discovery was only slightly less revolutionary than a trash can sliding across the floor to a shouted "lookout." Pavlov immediately began researching exactly what characteristics of an animal's experience caused a learned reflex to emerge.

The gain resulting from Pavlov's functional analysis of reflex behavior and his subsequent discovery can not be overestimated. Animals learn, thus proving that 1) animals were not substantially different than humans. There was continuity across species, exactly as Darwin had predicted and 2) that an important mechanism underlying the adaptation of human behavior had been identified. The last of the problems in explaining behavior that had baffled everyone from Descartes to Sechenov had been solved. While Spencer had suggested this type of process, Pavlov empirically proved it and carefully detailed exactly how and why it worked with a functional analysis.

1. animals were born with reflexive behaviors (unconditional)
2. animal reflexes did not need a mind, they were direct connections
3. animal physiological activities were reflexes (unconditional)
4. animal reflexes could be acquired or learned as the result of experience (conditional)

5. humans were continuous with animals and therefore governed by the same laws and were consistent with Darwin's natural selection
6. voluntary human behavior could be seen as the result of conditioning without the need of a mind as the explanation. Rather, the conditioning history was the explanation; voluntary behavior was nothing more than conditioned physiological activities

Summary: Acquired knowledge or adaptiveness was, at least in part, by way of an individual's ontogenic experience and that experience could be a stimulus paired with a reinforcer.

### B. Thorndike (1874-1949) [1905]

The context of commonly held beliefs at the time Thorndike did his research was: 1) Humans have innate unconditional S-R reflexes (i.e., pupillary reflex); 2) If voluntary behavior is practiced enough it becomes a direct S-R connection (e.g., typing without thinking about individual fingers operating individual keys); and 3) acquired direct S-R connections were called habits (the smoking habit or typing habit). A habit was a functional relationship that was conditional on the history of the person and was not inborn.

Thorndike's research questions were: 1) precisely what is associated with what when something is learned? (e.g., one possible answer, the cognitive processor one such as Kohler's would be that the idea-of-string was associated with the idea-of-release-from-the-situation which was in turn associated with the idea-of-pulling-the-string). 2) What is the process that makes all those connections happen, or what is required for associative learning?

Thorndike's question concerning what is associated with what when something is learned was effectively the same as Köhler's question. But Thorndike set it up correctly so that the actual environmental determinants of the behavior would be apparent. The animal would be "stupid" (i.e., a system that reacts to a cause) rather than the experimenter's explanation being stupid (i.e., some made-up tautological after the fact mental process). ]

Thorndike's procedures: He put cats into a puzzle box and observed them getting out. If the animal associated the idea of pulling-the-string-and-getting-out was associated with the puzzle box then the behavior change would be all or none, would occur in a one step realization, and the animal would "know" it from that point on. If pulling the string were an acquired habit (such as the typing habit), then the latency to escape would incrementally get shorter with increasing experience.

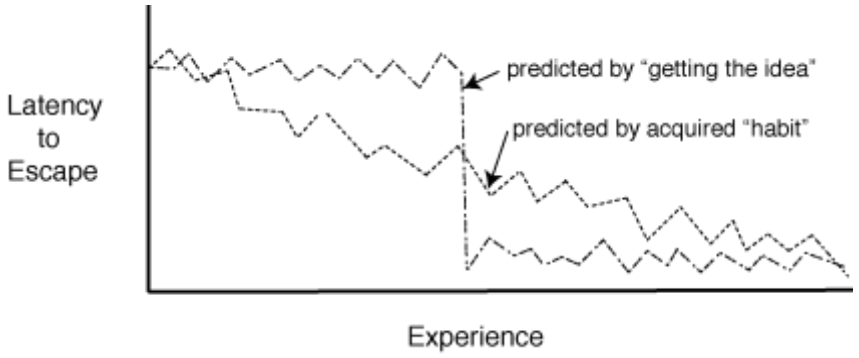



*Figure 8.6 Figure demonstrating the paradigm changing finding that adaptive learning was the slow development of a habit across successive trials across successive trials rather than an organism getting the idea of a solution. This revolution producing finding falsified mentalism. (Source xxxx)*

Thorndike's results: He found that the cats slowly and incrementally learned to get out. There was no single instant where the cat "got the idea." Thorndike's results were the same as those predicted by the incremental acquisition of a habit illustrated in Figure 8.6.

Thorndike's conclusion: the learning was not the idea of pulling string associated with the idea of getting out, learning was not the association of ideas, rather it must be a direct connection of the stimulus situation to the response, like the slow and incremental acquisition of typing or the slow and incremental acquisition of "automatic" smoking after a meal. It was a habit.

Thorndike also found that the animal's motivational state and the consequences of the behavior were critical to the acquisition of the habit.

Thorndike's paradigmatic contribution: ontogenically established learning was incrementally established connections between stimuli and responses or S-R habits, and the S-R connection was via the consequence of the behavior, much in the spirit of Hobbes and Spencer. However, unlike Hobbes and Spencer, Thorndike was an experimental scientist. He collected data to prove his assertion and did not have a made-up tautological mental process as an explanation. Following Thorndike, learning research was focused on incremental learning as the result of successive exposure to the learning task or "trials."

Thorndike was a behaviorist and did active research in a lab to understand the actual source of behavior (much like Ebbinghaus). Thorndike focused on the determinants of a behavior to a stimulus or an acquired SR connection when everyone around him was concerned with only the content of consciousness and ideas. He was like Galileo, Ebbinghaus, and Darwin in that he was focused on what actually happened and what in the natural world caused it. Consistent with the Darwinian revolution he used animal models to understand general laws of learning because it was now accepted that there was continuity between species. He studied the acquisition of new behavior rather than the playing out of old behavior. He used a quantitative method rather than a subjective one. From the previous acceptance of innate S-R connections in animals, Thorndike added acquired or learned S-R connections, and via Darwin, said all learning in all animals (including humans) was S-R habits and rejected the mind as an

explanation. The explanation of the new behavior was its conditioning history. Thorndike demonstrated himself not only smart, but rather brilliant. Thorndike was concerned with data and functional analysis rather than tautologies and rationalisms. Overt behavior (functional relations) was the subject matter rather than an opinion about the internal processes. In his view, it was the study of the effects of motivation and reinforcers on behavior that was the key to understanding how behavior came to be what it was, and the key to understand how each human came to be who they are. He added empirical proof to Spencer's assertion. Many of the advances to psychology attributed to Skinner were actually Thorndike's. Thorndike has been unjustly criticized for his subjectivism in his Law of Effect. In point of fact, he operationalized every term in the Law of Effect. It would seem that subsequent learning theorists and their followers were a bit too eager to differentiate themselves from those who went before them.

Summary: Adaptiveness was slow so it was not an animal "getting the idea." Rather it was the incremental development of a habit and that S-R habit occurred because of its consequences.

### C. Watson (1878-1958) [1913]

Watson was the philosopher spokesman of his time for rigorous research on the behavior of organisms as opposed to collecting anecdotal stories and making ad hoc guesses. Watson, in rejecting the mind and demanding that objective behavior be the focus of psychology, broke free from the trap of introspection and its limitation to humans.

In Watson's view "the study of the Mind is the province of philosophers; it is the realm of speculation and endless word games, if one separates observation (data and facts) from hypothesis, then behaviorism becomes a matter of epistemological necessity." Watson rejected magical causation but unfortunately he failed to dismiss the relevance of internal causation. To him it was a matter of lack of evidence rather than a lack of relevance. As a result, he was drawn ineluctably into postulating internal biological causes, debates that could not be resolved, and into offering hypotheses that were mechanistic internalisms. All were unsatisfying because ultimately they had no more empirical support than the competing mentalism.

Watson solidified S-R as a philosophical approach to psychology and permanently disgraced the mind as a cause of behavior. A learned functional relationship (i.e., short time scale adaptation) became the basic unit of behavior. It is important to note that "S-R psychology" implies that the behavior of an organism (i.e., R) is to be understood in terms of the environment, (i.e., S) not that the response must have an antecedent identifiable stimulus which immediately precedes it (S-R psychology is not equivalent to Descartes' mirror). Many people misunderstand the meaning of S-R psychology. No modern psychologist asserts that all behavior has an immediately prior localizable efficient stimulus that forces a very specific rigid response, such as those that Descartes or Loeb postulated for tropisms.

Even though no one today is a Watsonian behaviorist in every detail, the

fortunes of all psychologists including cognitivists now rise or fall on their connection to empirical reality even if some perspectives contain questionable assumptions. Anything else is seen as the metaphysical word games of amateurs. In that sense, today, everyone is a Watsonian behaviorist.

Summary: Watson shifted the focus of psychology from the opinions about mental events to objective behavioral events. After Watson, the burden of proof was on non-empirical entities. Even the most cognitive theories use empirical data as support or falsification of their inferred cognitive entity even if it is only affirming the consequences.

### D. Hull (1884-1952) [1943]

Hull based his explanatory system for how an organism acquired its behavioral repertoire on an eminently plausible homeostatic process. His strategy was to develop a formal principled internalistic quasi mathematical causal system which functioned much like an animal's nervous system. It could account for an animal learning: 1) to do things that resulted in good outcomes, 2) to avoid things that resulted in bad outcomes, and (3) to show the results of motivational levels. The core process was that need reduction such as eating or drinking increased the probability of the preceding behavior in the presence of the preceding stimuli. That process resulted in a fully adaptive organism without a mind making magical ad hoc decisions. Hull's theory could be considered a progenitor of artificial intelligence.

More specifically, his theory was based on acquired or learned stimulus response connections or "habits." Habits were acquired as the result of a favorable consequence following a response and were a change in the probability of a response given a stimulus. Effective consequences were effective to the degree that they decreased some need, such as eating reducing hunger. For example, if food were obtained by a hungry organism then that consequence would result in an increment in the habit or connection strength between the stimulus present at the time of the reinforced response and the response that had resulted in the food. In order to account for the effects of motivation, the behavior of an organism was governed by the habit strength between a stimulus and a response multiplied by the magnitude of the hunger need or drive [response strength = (habit times drive)]. As a result, Hull's theory accounted for both an increase in vigor with an increase in motivation and little or no behavior when the animal was satiated. That is to say, how much an animal responded was equal to the connection between the contextual stimuli and the response that resulted in the reinforcer, multiplied by the amount of deprivation the animal was experiencing.

His principled theory was more formal, complex, and sophisticated than the earlier theories of behavioral adaptation. Because it was principled it was adjustable and falsifiable and therefore evolved toward a better account for the actual behavior of actual animals. This quasi mathematical machinery had for its time, a remarkable ability to account for the behavior of organisms and brought an end to the earlier speculative tautological, ad hoc, theorizing that had up to that point characterized psychology. Hullian drive reduction theory was de

rigueur in the 1940s and 1950s.

The simplicity of the basic machinery underlying Hull's concept can be illustrated with a robotic vacuum cleaner. As the vacuum cleaner runs low on electricity (it gets hungry or has a drive), the intensity of its random activity increases because the various existing habits are energized by being multiplied by drive. Recall that response strength = (habit x drive). When the vacuum cleaner randomly bumps into an electrical outlet, it charges its batteries (need reduction) and an S-R connection is formed between the stimuli experienced just before the need was reduced and the behavior that had resulted in need reduction. For example the response of moving toward the sight of the outlet when batteries were low was learned

When the vacuum gets low on electricity again, it increases its vigor of randomly moving around again. If it encounters the stimuli that previously preceded food, it non-randomly repeats the same behavior it did just before getting the prior food because the vacuum had learned to do that behavior in the presence of those stimuli. If it does not encounter the same stimuli it learns some new path to the outlet and another S-R habit is added to the knowledge base. Higher-order conditioning adds the stimuli that immediately preceded the previously conditioned stimuli. Generalization spreads the correct behavior to stimuli that are almost the same. Repeated over and over, this process will extend a chain of behavior to stimuli out from the outlet in all the directions that the vacuum has ever experienced and to those in between. All those interlinked chains of stimuli and their responses take the vacuum straight to the outlet whenever its batteries are low again.

Significantly, if learning (habit) is the result of need reduction and if behavior is what is learned (habit) multiplied by need (drive) (i.e., behavior = habit x drive), **then an animal capable of surviving and benefiting from experience results**.

Hull's system evolved into a very complex system attempting to account for all learning in all situations. Eventually, it fell into disuse because 1) few researchers truly understood all the principles of the now very complex theory and how to predict with them, 2) New anomalous functional relationships uncovered by Hullian theorizing were difficult to integrate within the formal structure of the theory as enunciated in 1943. 3) The complexity of the explanatory system was increasing faster than the theory's ability to explain new phenomena. 4) Research activity became more focused on arguments about how the theory worked than on the observation of animal behavior, and 5) the broader paradigm failed to compete with radical behaviorism, as detailed below. What was originally a giant step towards science from mentalistic causation and unfounded speculation became too complex, inflexible and failed to attract new adherents. The widely used Rescorla-Wagner model could be seen as Hullian theory Part 2 and has had considerable success predicting behavior based on a similar but much simpler and coherent deductive model.

Summary: Hull had a principled internalistic homeostatic theory that could be used to explain a wide variety of complex behavior.

### E. Skinner (1904-1990) [1938]

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-term 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-term 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 understanding behavior. 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 sentences. 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. As a result, his paradigm attracted an extensive and diverse base of enthusiastic adherents. As a result, Skinner was the next step in the line from Bacon and Hume to Sechenov, Ebbinghaus, and Mach.

## 1. 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 discussion to functional relationships between the environment and behavior. He entirely removed unproductive discussions concerning what internalism caused the animal to respond. The previous two chapters of this text reviews the 2500 year bootless debate over why the animal responds. 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 8.7. 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"

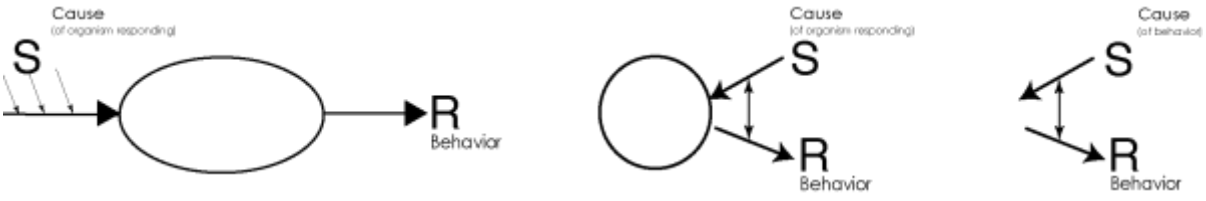



*Figure 8.7 The left section of this figure illustrates environmental events acting on an organism to cause the organism to behave in some way. The center section of the figure illustrates the same thing but diminishes the role of the organism by focusing on the causal factors and the behavior. The rightmost 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 person or pigeon.** 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).

### a. Conceptual Follow-up: Best Practice Versus Common Practice

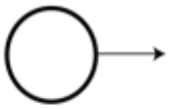
It is not as if there is anything necessarily and irretrievably destructive about 1) depicting the processes controlling the behavior of an organism as it is in the left portion of Figure 8.7; or 2) even saying "the child knew what to do." A diagram including an organism or a sentence with the organism 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 a goose retrieving eggs. The radical behaviorist saw egg retrieval when eggs were outside the nest.

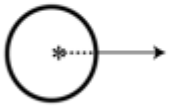
Radical behaviorism is a structuring of the environment to encourage the desired behavior from its practitioners, not some shibboleth or system to assign lower status to someone who speaks "incorrectly." It is nothing more than confining oneself to the necessary and sufficient elements of the field.

### b. Historical Evolution of the Conceptualization of the Cause of an Individual Organism's Behavior

Freewill as cause of organism's behavior (i.e. no cause) ...non science

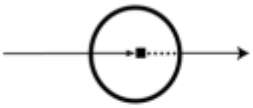


The mind as cause of organism's behavior ...non science

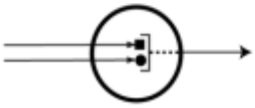


The mind as modulator of organism's behavior ...non science

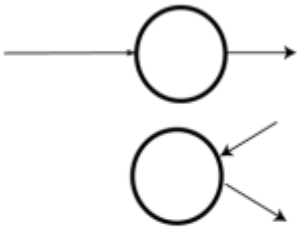
Environmentally determined cognitive process as cause of organism's behavior ...cognitivism



Environmentally determined cognitive process as modulator of organism's behavior ...cognitivism



The environment as cause of organism's behavior ... behaviorism



Prediction of behavior from environment ...radical behaviorism

### F. Rescorla ( ) / Wagner ( ) [1972]

The Rescorla/Wagner model is a general theory of behavioral adaptation with Pavlovian compound CS conditioning at its core. The amount learned is equal to a proportion of the amount left to be learned based on the predictability of the outcome based on all available stimuli. Many current theories of Pavlovian conditioning are based on variations of the Rescorla-Wagner model or are responses to it.

Depending on how effective the CS and US are, learning is faster or slower. If there are salient stimuli and a strong reinforcer, learning is faster. The formal specification for conditioning is $\Delta V = \alpha\beta(\lambda - \Sigma V)$, i.e., change in associative strength ($\Delta V$) equals = percentage ($\alpha\beta$) of (asymptote ($\lambda$) minus - total learned so far to all stimuli ($\Sigma V$)). Change in associative strength equals how salient the CS is, times how effective the US is, times (asymptote or the maximum learnable minus total learned so far to all stimuli).

If a stimulus such as a light is repeatedly followed by meat powder, it will be conditioned. If a bell and a light together are conditioned, then both will elicit salivation. However, if a bell and a previously conditioned light are conditioned together, then no salivation will occur when the bell is presented alone. The light will block conditioning to the bell.

The Rescorla-Wagner model was developed to explain a phenomenon of blocking in compound conditioning. Blocking had previously been explained by "attention" (a mental activity). Subjects were said to pay more attention to one CS rather than another. The term attention is vague and is typically only invoked after the fact to rationalize the outcome. The Rescorla-Wagner model is precise and can be applied not only to explain blocking but also other phenomena such as conditioned inhibition, overshadowing, and over-expectation. In a phrase, the Rescorla/Wagner model has had tremendous success in predicting results. The model can be seen as a strictly externalistic specification of how the probability of a behavior will change as a function of specific stimuli, however, its proponents are most often non-empirical internalists.

Summary: A simple principled equation that specifies how behavior changes as the result of exposure to the correlation of stimuli with reinforcers can account for a wide variety of functional relationships.

### G. The Future of Learning (Short Time Scale Adaptation) Theories

The Experimental Analysis of Behavior traces its philosophical roots from Aristotle, Galileo and Descartes to Hobbs, Spencer, Sechenov, and Skinner. It traces its epistemological roots from Bacon, Hume, Mach, Watson, Wittenstein, and Skinner. It traces its methodological roots from Mill, to Ebbinghaus, James, Pavlov, Thorndike, and Skinner.

The seminal realization that the prerequisite elemental issue in psychology was how an individual organism's repertoire came to be as opposed to simply detailing examples of the adaptation of a "knowing" organism is attributable to Spencer. The behavioral adaptation resulting from pairing a neutral stimulus with a functionally significant one was first experimentally identified by Pavlov

and is therefore often labeled Pavlovian conditioning. The adaptation resulting from the consequence of an arbitrary behavior was first experimentally identified by Thorndike and is often labeled Thordikian learning. Watson lucidly and forcefully made Ockham's point: talking about anything other than objectively provable things is unproductive, and even disgraceful.

Skinner's claim to fame was that he integrated all these details into a coherent, principled and pragmatic paradigm that was explicitly focused on an externalistic functional analysis of the moment-to-moment adaptation of an individual's behavior. That adaptation was to be understood and explained by the behavior's history of Thordikian reinforcement. His approach to psychology, Behavior Analysis or Radical Behaviorism, is the progenitor of what all psychology will be in the future. Currently, it is often labeled Skinnerian Psychology by non-behavior analysts. Skinner's approach to organismic adaptation targeted to applied issues is labeled Applied Behavior Analysis or ABA, while his approach when targeted to research questions is labeled the Experimental Analysis of Behavior or EAB.

Pavlovian conditioning has received substantial research interest since the pioneering work of Rescorla and Wagner. Unfortunatly, much of the explanatory framework has been cognitive. However, this important form of short time scale adaptation has a developing behavior analytic framework and offers the prospect of providing an explanatory context for what have otherwise been anomalous relationships.

# CHAPTER 9

# Conceptual Issues Pertaining to Short Time Scale Organismic Adaptation

## I. Formal Overview / Review of Short Time Scale Adaptation

A. The significance of short time scale adaptation and why behavior analysis is strongly focused on it
B. Defining properties of short time scale adaptation
C. Trial by trial example of short time scale adaptation
D. The characteristics of short time scale adaptation
E. Assessment procedures for short time scale adaptation
    1. The emergence, acquisition, or origin of behavioral adaptation to a change in conditions (direct assessment)
        a. Emergence of the topographical characteristics of the behavior
        b. Emergence of the stimulus control over the behavior
    2. Comparison of the asymptotic expressions of adaptation in two different situations (indirect assessment)

## II. Aspects of Short Time Scale Adaptation

A. 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
B. Conceptualizations of the elements in short time scale adaptation
    1. Paradigmatic interpretations of the behavior
        a. Definitions of behavior as some direct change in a physical measure or an act
            i. Definitions of behavior as defined by simple informal observation of physical activity
            ii. Definitions of behavior as defined by its specific impact on the environment
            iii. Definitions of behavior as genetically related to the subsequent outcome or consequence

iv. Definitions of behavior as a homologue of behavior in other species

b. Conceptual follow-up: the relationship between the empirical response and the conceptual "response"

i. Conceptualizations of behavior as some higher order aspect of physical measures

2. Paradigmatic interpretations of the arbitrary stimulus or "cue"

a. Conceptual precursor: the potentially subtle and elusive nature of controlling stimuli

b. A stimulus as an environmental change that is necessary and sufficient to control a behavior change i.e., a functional relationship

c. Labels/metaphors for stimulus control (immediate time scale adaptation or reactions)

i. Control
ii. Elicit
iii. Educe
iv. Induce

d. Types of stimuli that could have a functional relationship with a behavior

i. Explicit stimuli
ii. The behavior of the organism itself as a stimulus
(1) Epistemological fine point
iii. The passage of time as a stimulus

e. Sources of variance in stimulus control

3. Paradigmatic interpretations of the subsequent outcome

a. Conceptual precursor: how reinforcement is conceptualized can be seen as a core concept of behavior analysis

i. An interesting historical side note

b. Preeminence of the correlation of the subsequent outcome with antecedent events in short time scale adaptation

c. Characterization of the subsequent outcome

i. Consequence / outcome as a stimulus
ii. Consequence / outcome as a behavior

d. Manifestation of the subsequent outcome

i. Presentation of the outcome
ii. Removal of the current condition

e. Conceptual precursor: metaphors and determining useful labels and graphics for entities, processes, and functional relationships thought to characterize short time scale adaptation

f. Metaphors / labels for the effect of the subsequent outcome

i. Reinforce, strengthen, increase, augment, induce
ii. Attach, connect, unite, bind
iii. Select, choose
iv. Reinforce in the presence of a stimulus
v. Graphical depictions of events at moment of reinforcement

C. Generality of functional relationships which originated as the result of short-time scale adaptation
1. Formal principled determination of generality
2. Generality based on correctly intuiting an extension into a unique situation
3. Generality based on correcting a failure to extend into a unique situation
4. Conceptual follow-up: broadening the database in order to increase generality

## III. Formal or Scrupulous Usage and Problematic Issues

A. Environmental “events" are actually environmental changes
B. To “strengthen” a response is actually to increase or maintain the probability or momentum of a response class given a stimulus class
C. “Behavior” actually refers to a behavior change under stimulus control (i.e., a functional relationship)
D. Traditional but problematic focus on only terminal behavior or the operant
1. First remediation strategy: assess terminal behavior in all portions of the imminence of reinforcement gradient or across the entire interreinforcer interval
2. Second remediation strategy: assess reliable behavior other than the terminal behavior or operant in all portions of the imminence of reinforcement gradient or across the entire interreinforcer interval
E. Traditional but problematic short-trials methodology
F. Traditional disinterest in a detailed characterization of the effects of stimuli negatively correlated with reinforcement
G. Insufficient principled conceptualizations specifying how response strength generalizes or extends across stimulus dimensions
H. Insufficient principled conceptualizations specifying how sets of local contingences can come to function as a global contingency
I. Notable under researched contingencies
J. Speculations pertaining to why the outcome functions as it does
1. Inferred internal homeostatic processes
a. Inferred optimization of drive or need state
b. Inferred optimization of an internal state by preparation for consummation
2. Inferred optimization of the time course of any induced behavior

## IV. Detailed Presentation of the Functional Relationships Involved in Short time scale Adaptation

A. Conceptual review: the preeminence of ontogenic contingency history in understanding short time scale behavioral adaptation
B. Conceptual review: understanding the emergence or acquisition of short time scale adaptation
C. A stimulus reinforcer correlation or a Pavlovian contingency
    1. Specific instantiations of Pavlovian conditioning
        a. Simplistic trial-by-trial example of Pavlovian conditioning
        b. More complete phase-by-phase example of Pavlovian conditioning
D. A response reinforcer correlation or a Thorndikian contingency
    1. Specific instantiations of Thorndikian conditioning
        a. Simplistic trial-by-trial example of Thorndikian conditioning
        b. More complete phase-by-phase example of Thorndikian conditioning
E. Conceptual follow-up: diversity of presumed relationships between Thorndikian and Pavlovian conditioning
    1. Thorndikian and Pavlovian conditioning are totally different
    2. Thorndikian and Pavlovian conditioning are totally the same
    3. All short time scale adaptation is via S-S* contingencies
    4. All short time scale adaptation is via R-S* contingencies
    5. Functional approach: there are procedures that cause short time scale adaptation
F. A stimulus controlling a response or stimulus control
    1. Conceptual precursor: a figure simultaneously exemplifying the emergence and the asymptotic expression of stimulus control for both terminal and other behavior in each portion of the imminence of reinforcer gradient
        a. Parceling out the emergence and asymptotic expression of terminal behavior and behavior across the entire interreinforcer interval
            i. The emergence of terminal behavior
            ii. The asymptotic expression of terminal behavior
                (1) Behavior analytic terminology for the emergence and asymptotic expression of stimulus control over terminal behavior across the experience axis
            iii. The emergence of behavior across the entire interreinforcer interval
            iv. Asymptotic behavior across the entire interreinforcer interval

# CHAPTER 9

# Conceptual Issues Pertaining to Short Time Scale Organismic Adaptation

## I. Formal Overview/Review of Short Time Scale Adaptation

Living things behave. If an organism is observed, it can be seen to do many different things that vary in many different ways. A bee may flit from one flower to another, a person may sing, run, or sleep.

Of all the characteristics of behavior the most important is the capacity of behavior to change or adapt to events in the environment across immediate, short, medium, or long time scales. Organismic adaptation can be seen as the equilibration of a system to an environmental change. An eye may blink to a puff of air. A heron may come to regularly go to a new specific spot in a creek to fish over the course of the summer, a dog having lived in a war zone may come to exhibit exaggerated fear of noises for decades later, or a population of fruit flies may change its courtship behavior and that change carries over to subsequent generations even if the fruit flies have no opportunity to ontogenically learn that new behavior.

The difference in these time scales of behavior adaptation is quite important and has been detailed as time scale of organismic adaptation in Chapter 1. The ongoing behavior of an individual simultaneously contains equilibrations that have occurred across all time scales, much like a symphony is the combination of the various frequencies and amplitudes of all the notes of all the instruments in an orchestra. Figure 9.1 illustrates this relationship. The elements marked with gray emphasize short time scale adaptation which is the specific adaptation of interest to EAB.

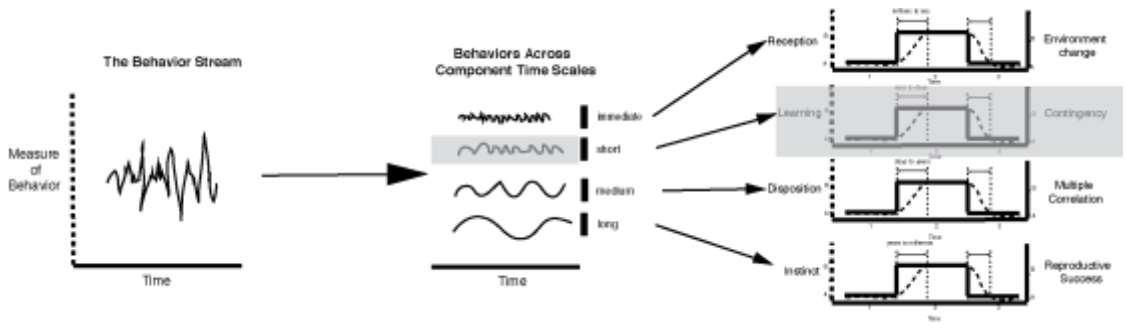



*Figure 9.1 The complex waveform in the left portion of the figure represents the complex behavior of an organism. That complex behavior can be seen to be the sum of many different simple*

*components illustrated by waveforms depicted in the center portion of the figure. The right portion of the figure represents the formal definitions of the different time scales of adaptation that contribute to the total behavior stream shown in the left section of the figure. Short time scale adaptation, the focus of interest to EAB and the topic of this course, is highlighted in gray.*

### A. The Significance of Short Time Scale Adaptation and Why Behavior Analysis is Strongly Focused on it

The ability to behaviorally adapt as the result of specific ontogenic experiences 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. It wasn't until the era of straw hats and barbershop quartets just before World War I that Pavlov and Thorndike using rigorous and objective procedures proved that humans were not the only living things that could adapt or benefit from experience within their lifespan. As ignorant as it seems, before Pavlov and Thorndike the belief was that humans had a magical and unique ability to benefit from experience.

The task of a student of EAB is to understand the functional relationships to which an organism is exposed which have, adaptation as a result, What procedures lead the organism to engage in behavior that correctly and efficiently produces a positive outcome that appears "smart"? How can the experimenter come to know enough about the needed experiences to be able to specify the real world determinants of the behavior and show that the organism is not magical and is just an accumulation of elements in the natural world, not fundamentally different than the contents of a trash can, exactly like we would want to know what makes a smart phone work or a goose retrieve its egg – everything else is a waste of time.

A common factor in the behavioral adaptation demonstrated by Pavlov and Thorndike was that when stimuli or behavior repeatedly precede a significant outcome, it incrementally eventuates in an asymptotic increase in adaptation.

Skinner focused the diffuse and difficult to manage concept of "behavior" into a clearly defined easily measurable entity, such that its occurrence/nonoccurrence and its probability could thereby be reliably specified and quantified. Skinner's formulation of the "operant" had no less of a revolutionary impact on our understanding of psychology than reinforcement itself.

A pigeon coming to peck a key as the result of key pecks being followed by food presentation is a prototypical example of short time scale adaptation, and is taken as a model of virtually all behavior maintained by Thorndikian reinforcement.

### B. Defining Properties of Short Time Scale Adaptation

The definition of short time scale organismic adaptation is: a semi-permanent change in the behavior change to the presentation of a stimulus

change, as the result of the relationship of that stimulus and/or behavior change to subsequent functionally significant events in the environment. The obtained behavior change across successive exposures to the learning task (a functional relationship) exhibits hysteresis in the seconds-to-days range on both the onset and offset of the change in the systematic environmental relationship[the solid line]. That is to say that across a block of exposures or trials, the behavior to a stimulus changes[the dashed line], and that change shows relative permanence. This short time scale adaptation could be seen as optimal when the specific demands of the environment change many times within the life of the individual. Figure 9.2 illustrates the details of this short time scale adaptation

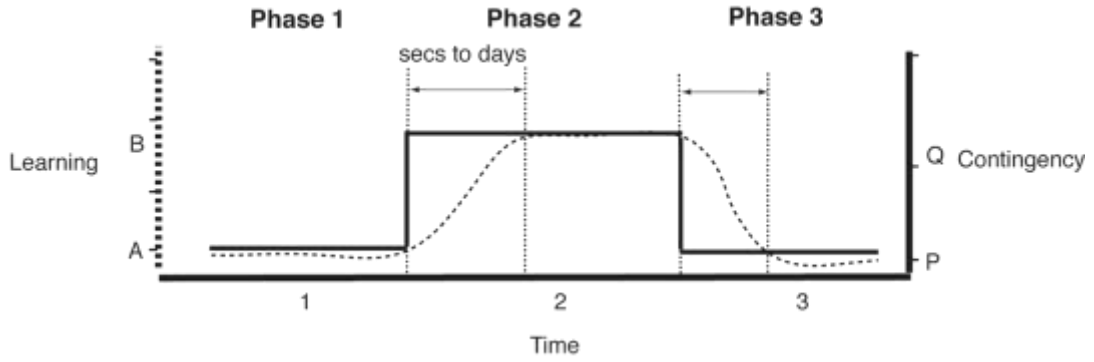



*Figure 9.2 This figure is a re-presentation of Figure. 1.5. After an initial state of equilibrium at Time 1 between the independent variable (depicted with a solid line) and the dependent variable (depicted with a dotted line), the independent variable changes from State P to State Q. Following a lag in the seconds-to-days range, the dependent variable changes to State B and comes into equilibrium with the independent variable at Time 2. 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 at Time 3.*

Recall: 1) that the environmental change (represented by the thick solid line in Figure 9.2) does not represent simply the occurrence of a stimulus; rather it represents a change in a systematic nonrandom relationship in the environment (for example, each key peck to the green key is now followed by food where previously it had not been followed by food); 2) that the dependent variable represented by the dashed line) is not simply a response, but rather is the acquisition and maintenance of a new semi-permanent response class to a stimulus class across repeated instances of the same stimulus change and reinforcement contingency (for example, the acquisition and increase and maintenance of the number of pecks to each successive instance of the green key light going on as the result of key pecks being reinforced during that stimulus). This change in behavior is often labeled conditioning or learning; and 3) that short time scale adaptation is not conceptualized as the organism coming to know what to do; or some internal change that is not necessarily correlated with any measurable output. Rather it refers to the semi-permanent

change in the ability of a stimulus change to control an explicit behavior change. This adaptation, conditioning, or learning is a totally externalistic functional definition. Internal characterizations of that functional relationship are seen as irrelevant. Those irrelevant characterizations would include the brain changed, the cognitive processing center came to know what to do, and the space aliens transmitted a signal to do the behavior. These adaptations take a short time to emerge. It is a change from a specific behavior difference to a stimulus change, to some new reliable, semi-permanent behavior difference to the same stimulus difference. As an alternate example, initially a bell but not white noise could control salivation, subsequently white noise but not a bell could reliably and semi-permanently elicit salivation.

This class of behavior adaptation includes behavior changes to repeated occurrences of the same stimulus reinforcer pair (such as a bell followed by meat powder), and to repeated occurrences of the same response/reinforcer pair (such as a key peck followed by food). Both resulting adaptations show both onset and offset hysteresis in the seconds-to-days range. A behavior semi-permanently occurs with a higher probability following the stimulus, comes under the control of, or is "connected" to, a stimulus. Those semi-permanent adaptations are labeled short time scale adaptation and are **labeled** associative.

The resulting stimulus control can be very obvious such as the pigeon coming to immediately peck a green key light whenever it comes on, or could refer to the more diffuse control exerted by the general pigeon chamber environment on pecking, or even a behavior change that takes place only after a delay. For example, someone can be told a phone number and not call it for weeks. (Note that the term learning can not be used until there is evidence of the correct behavior.) It is important to also note that the relationship is not necessarily a one to one relationship such as if A then B or if you move one end of a stick then necessarily the other end of the stick also moves, rather the relationship is probabilistic such as if A then B occurs with a higher probability and that probability could vary from a small but significant increase to the inevitable occurrence of the response given the stimulus.

### C. Trial by Trial Example of Short Time Scale Adaptation

Short time scale adaptation is the focus of EAB. As a result of the correlations between antecedent events and subsequent outcomes, the functional properties of the behavior are changed in a fundamental and semi-permanent way. 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 a correlation. Where stimulus *x* had resulted in behavior $\propto$; following sufficient exposure to the correlation, the same stimulus, *x,* results in behavior $\beta$. This capacity is well beyond most simple input output systems. This change is illustrated in Figure 9.2 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.

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 ∝ and not behavior β. This is illustrated by the hysteresis of the dependent variable in Figure 9.2 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. This class of adaptation illustrated in Figure 9.2 does not spontaneously reverse with the passage of time. This adaptation requires the exposure to contrary contingencies to reverse. Figure 9.3 depicts the procedures and results from two subjects across three phases. Please carefully step through each of the twelve trials for each individual under each phase and note how the dependent variable changes (or not) with each of the twelve experiences in each case.

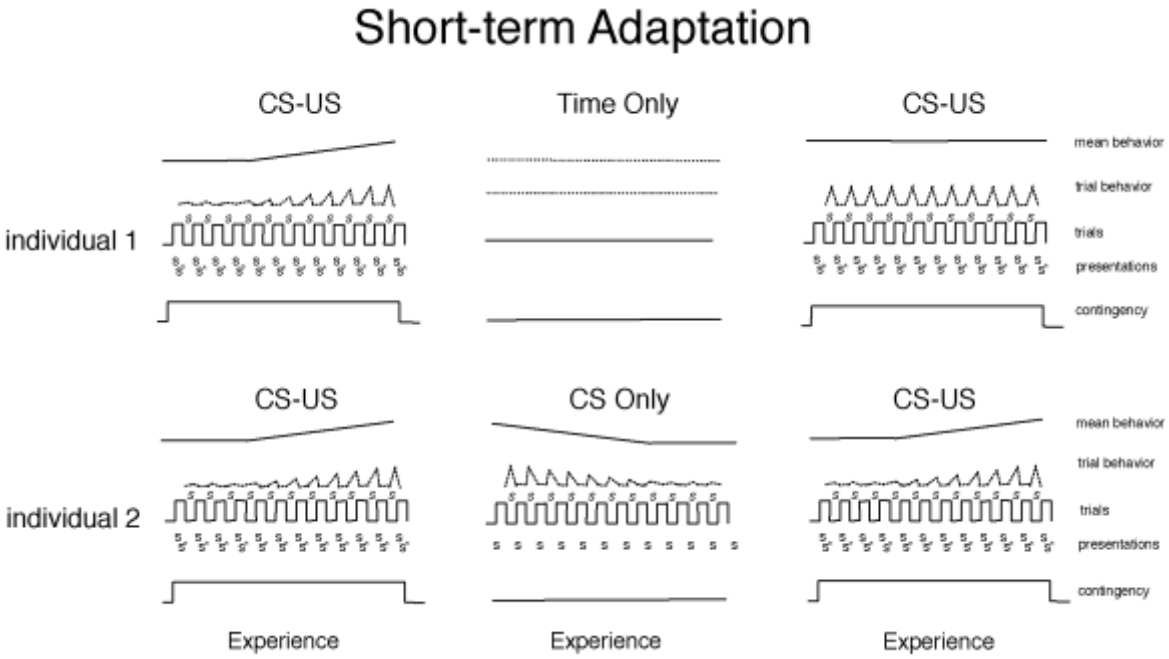



*Figure 9.3 The figure presents procedures and data from two individuals exposed to procedures in order to illustrate short time scale adaptation. In the left column, both individuals show a behavior change with experience. The CS S* pairs just below the middle of each frame with each of the twelve square waves denoting trials represent a series of presentations of a stimulus immediately followed by the US (and admittedly the CS and S* lines are too fine to see). The single long square wave just below the CS S* pairs designates instances of the experimental treatment (i.e., presenting the CS US contingency). The dotted line sawtooth above the square wave depicts instances of the behavior or dependent variable. The behavior to the CS can be seen to grow stronger with each successive trial (the height of the sawtooth grows higher). The dotted top line in each frame of the left column represents the average strength of the dependent variable and documents the increase in strength exhibited by the dependent variable. The center column shows that Individual 1 then experiences only the passage of time while Individual 2 experiences trials with no US (i.e., extinction). No behavior occurs in Individual 1 with only the passage of time. Individual 2 shows a slow loss of behavior across the exposure to extinction. The training*

*effect took time to go away and therefore had been semi-permanent. Finally, the right column illustrates that when given trials with CS US pairings again. The individual exposed to only the passage of time shows that there had been no loss of the effect of the CS (i.e., absent a procedure to remove the learned behavior it was permanent), while the individual exposed to extinction had lost the original learning across the course of extinction and therefore exhibited a relearning curve when the treatment was reinstated.*

In the first phase of this experiment, each animal is subjected to 12 occurrences of a CS paired with a US (bell and meat powder) or trials. The behavior to the CS asymptoticly increases in magnitude across the 12 trials of Phase 1 in both animals. In Phase 2, one animal experiences only the passage of time. The other animal receives CS exposures without a subsequent US (extinction). Phase 3 is a repeat of Phase 1. For the animal with exposure to time only, the behavior on the first trial of Phase 3 is the same as the last trial of Phase 1. For the animal with an exposure to extinction, the behavior had extinguished or disappeared. For this animal, the behavior on the first trial of Phase 3 is the same as on the first trial of Phase 1. Note in Figure 9.3 that: 1) the block of training time in Phase 3 for Animal 1 shows that the behavior picks up where the block labeled acquisition left off, and 2) the block of training in Phase 3 for animal 2 that received explicit extinction exposure shows that the behavior acquired in Phase 1 had disappeared. The first trial of Phase 3 is the same as the first trial of Phase 1.

### D. The Characteristics of Short Time Scale Adaptation

(1) The ability of a stimulus difference to control a 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) The 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" or "learning and motivation"
(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

### E. Assessment Procedures for Short Time Scale Adaptation

As with most assessments, the general methodology is to claim that the difference in the behavior is the result of the difference in the procedures or chance. Short time scale adaptation can be assessed either by 1) changing the

contingencies and observing the emergence of a different behavior to the stimulus (first illustrated in Figure 1.18), or by 2) comparing the asymptotic expression of behavior under two different contingencies (first illustrated in fig 1.19)

### 1. The Emergence, Acquisition, or Origin of Behavioral Adaptation to
#### a. Change in Conditions (Direct Assessment)

This is the procedure used to define time scales of adaptation. It is the direct and at least at first blush, the most obvious method of assessing adaptation to some changed procedure.

The emergence measure illustrated in Figure 9.4 is the transition from some procedure considered a zero state to some asymptotic performance, to a different procedure. The difference in the behavior is attributed to the difference in the procedures. It 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). It would be labeled a behavior dynamic.

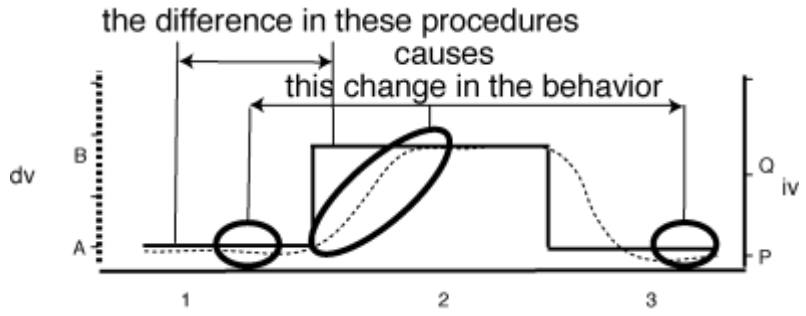



*Figure 9.4 This figure is a re-presentation of Figure. 1.18. This figure depicts the emergence or acquisition in a dependent variable (dotted line) as a function of a change in the independent variable (solid line). In sum, the change or difference in the dependent measure is caused by the difference 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.*

#### b. Emergence of the Topographical Characteristics of the Behavior

The emergence of a simple reaction itself, such as the emergence of a key peck (immediate-term adaptation) could be measured by turning on a light and measuring the details of the head movement as the head approached the key. In this case, the dependent measure is the emergence or occurrence of the reaction itself. Alternatively, a reinforcer could be provided for each occurrence of a keypeck and the change in the probability of a keypeck over time could be recorded, a cumulative recorder is often used to document the emergence of an operant.

### c. Emergence of the Stimulus Control Over the Behavior

The emergence or acquisition of stimulus control over short time scale adaptation or learning could be directly observed by documenting how a keypeck comes to occur to only a green key rather than to any color key by reinforcing pecks to to a green key but extinguishing key pecks to any other key color.

## 2. 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 equilibrium / 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 9.5. 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 procedure is a comparison of two procedures.

In Behavior Analysis, the interest is often on assessing how an asymptotic immediate-term reaction is expressed under two different short time scale contingencies. For example, learning could be studied by documenting a reaction or the asymptotic expression of a behavior (immediate-term 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.

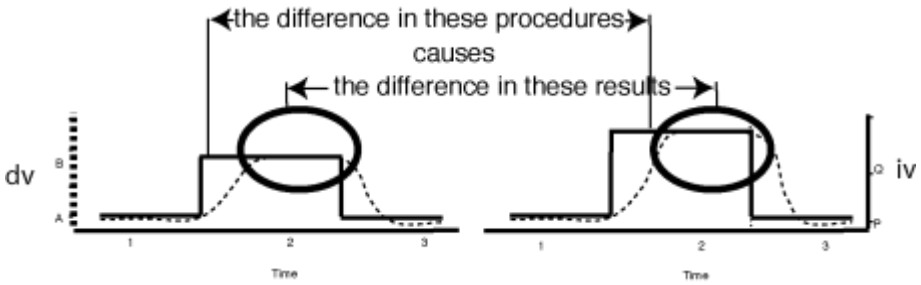



*Figure 9.5 This figure is a re-presentation of Figure. 1.19. This figure depicts the difference in the asymptotic expression or performance of a dependent variable (dotted line) as a function of a difference in the independent variable (solid line). In sum, the difference in the dependent variable is caused by the difference in the independent variable*

# II. Aspects of Short Time Scale Adaptation

### A. The Three Functional Relationships Fundamental to Behavior Analysis

The task facing behavior analysis is to understand short-term 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 is irrelevant because it does not provide the data at the same level as the functional relationship of interest. Declaring that a rearrangement of quantal particles causes short time scale adaptation would be fatuous.

Specific relationships between the three elements given below in Figure 9.6 have been shown to be the necessary and sufficient elements for the appropriate explanation for the emergence or expression of the short-term behavioral adaptation of an organism.

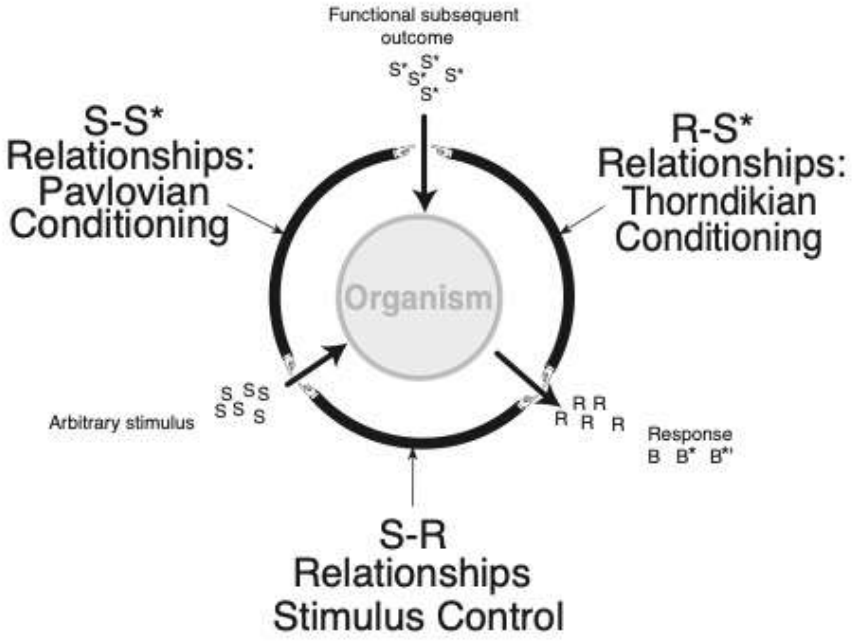



*Figure 9.6 An illustration of an organism (gray circle) and three types of events: stimuli in the lower left, responses or behavior in the lower right, and reinforcers at the top. The functional relationships of interest in behavior analysis are: S-S* (Pavlovian conditioning) noted in the upper left 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-term 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 9.4 are the independent variables. The functional relationship illustrated in the lower quadrant of Figure 9.6 and labeled stimulus control is the dependent variable or outcome 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-term 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 what is labeled 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. It is an immediate time scale effect, and can have its origin across any of the other time scales. When the term is applied to short term adaptation this behavior has its origin in Thordikian or Pavlovian contingencies. 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.

## B. Conceptualizations of the Elements in Short Time Scale Adaptation

### 1. Paradigmatic Interpretations of the Behavior

An individual's behavior includes all those things that a live animal does, that a dead one does not. Luckily, given that our task is only to understand the short time scale adaptation of the behavior of individual organisms, our task is limited to only the functional relationships pertaining to that time scale. A simple video including the context as well as the physical, auditory, olfactory, and other behaviors of a living animal across its life span would be a complete record of everything the individual animal did and would therefore be a complete record of any of its short time scale adaptions. But, the data would be very difficult to analyze. It would be impossibly large and impossibly complex. Fortunately, the task of science is to explain more with less and not simply to collect data.

The behavior analytic approach to understanding the short time scale adaptation of individuals is to chose an atomistic representative unit of behavior and document the change in its characteristics as the result of events in the environment, and then to use the obtained functional relationships to develop an explanation for all behavior of all organisms in all contexts through a principled explanatory system.

The history of the unit of behavior in psychology has progressed from "a human understanding the meaning of life;" to "a human perceiving a thing"; to "an animal learning its way through a maze"; to "a rat choosing a right or left turn"; to "a rat pressing a lever or a pigeon pecking an illuminated disk". The simplification of the behavior to a well defined revealing stimulus response relationship and the growth in the ability to validly generalize this functional relationship to other situations has given us our current success in understanding and explaining the behavior of organisms.

The choice of the "unit of behavior" is determined by several factors, but first and foremost is that the obtained functional relationships must reliably and validly predict results in other situations and simplify the understanding of the

short time scale behavioral adaptation in individuals. Other factors include the interest of the researcher, and practical factors pertaining to the conduct of the research.

### a. Definitions of Behavior as Some Direct Change in a Physical Measure or an Act

#### i. Definitions of Behavior as Defined by Simple informal Observation of Physical Activity

These definitions of behavior include examples such as the observation of a rooster crowing in the morning, or a person smiling at a friend. Unfortunately other behaviors of the subjects may or may not be relevant to understanding the target behavior. Additionally, informal observations of behavior are generally unreliable both within and across observers.

#### ii. Definitions of Behavior as Defined by Its Specific Impact on the Environment

(e.g., an operant). These behaviors flow from Skinner's version of the Thorndikian conditioning paradigm. An operant is any response with the same effect on the environment (e.g., opening a door, or the activation of a sensor). For example, a key peck is a key peck regardless 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. Note that this approach leads to considering a pigeon key operated by backing into the key as an important behavior, while a head motion toward the key that does not touch the key as an irrelevant behavior. It is not paradigmatically important to consider behavior that was not measured or detected by the transducer. 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 impact immediately preceded the reinforcer.

To reiterate, one of the substantial ramifications of a operant conceptualization is that **all** of the behavior of interest is detected and **none** of the "other" behavior is recorded, **by definition**. If it fails to operate the recording device, then it does not meet the criterion for being considered a response. A behavior that fails to operate the sensor is not the same behavior class as the one immediately preceding the reinforcer. As a result, there is a one-to-one correspondence between what is measured and what is of paradigmatic significance.

This definition is sometimes labeled a "functional" one. 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 usage is also different than the evolutionary biologist's usage which refers to

the evolutionary advantage provided by the behavior. Carefully attending to the context in which the term “functional” is used will usually clarify its intended meaning

### iii. Definitions of Behavior as Genetically Related to the Subsequent Outcome or Consequence

(e.g., a respondent). These behaviors flow from the Pavlovian conditioning paradigm. The definition of Pavlovian short time scale adaptation is that an arbitrary stimulus comes to control a "fixed" response. The choice of exactly which of many behaviors is used as the dependent variable is arbitrary but only within a range. The criterion is that the chosen dependent variable must pertain in some way to the unconditioned response to the reinforcer. A wide variety of measures are possible. They would include the initial reactions and any compensatory reactions to those reactions, measured at any level of the organisms. The particular research interest determines the selection. For basic questions pertaining to Pavlovian conditioning in general, its likely any behavior controlled by the reinforcer would adequately serve. For various applied research questions specific details of how the CR relates to the UR would be relevant. which is a challenging task. The total and precise UR may never have been characterized to date. For example, every single digestive process may be affected to one degree or another in a "simple" salivation conditioning procedure, and the details may change based on the chemical or physical properties of the reinforcer. Additionally, the apparent UR in an adult organism may contain many CRs that had been conditioned over the organism's life span as the result of earlier natural intrinsic conditioning contingencies.

Substantial questions remain concerning how a CR relates to the UR: 1) while the CR and UR appear to be the same in simple salivation conditioning, the CR and UR are very different in a procedure with shock as a reinforcer. This anomalous effect may be the result of a lack of clarity with respect to how the various behavior systems such as "searching", "stalking", "capturing", or "consuming" are selected as the CR. For example, in some given Pavlovian procedure, it may be possible to select to measure "the" UR and "the" CR one way such that they are very similar. However, it may be that selecting other behaviors measured in some other way results in "the" UR and "the" CR being quite different. 2) The CR often does not have components that are present in the UR. It's possible but not necessarily the case that the discrepancies could be attributed to the difference in the US and CS and the resulting difference in the reaction chains controlled by the difference in those stimuli. For example, a food unconditioned stimulus may result in a swallowing UR while an auditory CS may not contain a swallowing response because the swallowing was part of a reaction chain to food in the back of the throat. Many questions pertaining to the correct characterization of the CR and the UR and their relationship are pending further research.

#### iv. Definitions of Behavior as a Homologue of Behavior in Other Species

(e.g., comparative psychology / animal behavior). These behaviors flow from the comparative psychology or ethology paradigm. The dependent variable is selected because its expression has some function in common with some homologous behavior in another species. By comparing the similarity and differences in the behavior to the similarity and differences in the species, an understanding of long-term adaptation or the evolution of the functional relationship can be constructed. These types of considerations would be critical to those perspectives that conceptualize short time scale adaptation or learning from an evolutionary context.

### b. Conceptual Follow-up: The Relationship Between the Empirical Response and the Conceptual "Response"

There are an extremely wide variety of potential behaviors (e.g., position in space, vocalization, etc.) and potential dimensions (e.g., duration, intensity, etc.) which could be used as dependent variables in order to understand the short time scale adaptation of any behavior in any individual organism.

Our current understanding of behavior has been based on a "voluntary" skeletal behavior of a pigeon or rat reinforced with food, with the response rate taken to index the probability of behavior as a function of the relative imminence of reinforcement. It has been phenomenally successful. The functional properties of this behavior has successfully modeled behavior as diverse as verbal behavior reinforced by social approval in humans, the strategy for avoiding predation in fish, and leadership behavior in heads of state. As a result, behavior analysis has pretty much settled on the key peck and lever press as the prototypical behaviors, and response count, frequency, and choice as the prototypical dimensions. Unfortunately, in many cases, the generality of the research is too dependent on the wisdom of the researcher or practitioner. This situation is suboptimal.

#### i. Conceptualizations of Behavior as Some Higher Order Aspect of Physical Measures

Any unit of analysis pertaining to an organism includes many finer units and is itself a component of a more complex and larger and larger units. This relativity applies to both response units (e.g., a muscle twitch to a journey) stimulus units (e.g., light flash, to all the words in a book) and for contingencies (e.g., higher reinforcement rates for higher response rates). The chosen unit or level on which to focus is therefore somewhat arbitrary.

Figure 9.7 illustrates three different classes of molecularity. The first behavior example on the left is made up of longer temporal units; the second, depicted in the center, is made up of higher and lower elements in a hierarchical structure, while the third, illustrated on the right, simply contains more elements.

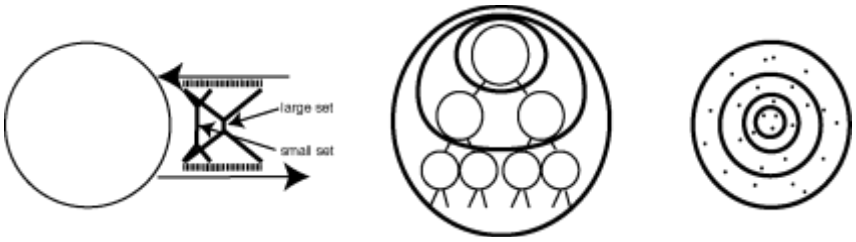



*Figure 9.7 Illustrations of three different kinds of "degrees of molecularity." The left figure illustrates longer and shorter temporal groupings. The middle portion of the figure illustrates smaller and larger groupings of hierarchically organized elements, while the right portion of the figure simply illustrates more or less elements.*

The degree of molecularity of the behavior measured may be nothing more than grouping size but could entail additional processes. In that case, we would need new principled laws for the higher order functional relationship that relate the more (or less) complex behavior to the more (or less) complex environment, as well as specifying when each is applicable In this latter case, the higher order measure may be an essential component of the explanation for the behavior. It is important to note that higher order measures are based on the functional analysis of empirically measured occurrences of specific physical acts

The use of finer degrees of molecularity in the study of behavior could be argued on evolutionary grounds. The logic being, if evolution advances by establishing hierarchical assemblies to produce more and more molar behaviors, then It is likely that evolution, at least in some cases, proceeds in small steps and relatively small units would therefore have wide generality.

The degree of molecularity or unit of behavior had a very important impact in early theorizing about behavior. The difference between Hull and Tolman could be seen as the difference between attempts to explain the factors causing footsteps versus attempts to explain the factors causing journeys. In Hull's case, research focused on what altered the steps taken to attain the goal. Tolman on the other hand focused on goal attainment as a unit. In Tolman's case research assessed what precipitated or terminated the goal attainment. Hull was considered an atomist while Tolman was considered a holist.

In sum, The explanation of something that the organism does can be explained by reference to a **physical act** or by some **higher order set of physical acts**. Research based on a higher order measure of behavior is of paradigmatic interest when there is reason to believe that an organism's short time scale adaptation is controlled by it. An example of this "assembly level" issue is exemplified by the interpretation of why a VI schedule and a VR schedule maintain different response rates. From one view, it is the probability of individual short IRTs being reinforced (a direct consequence of the occurrence of a specific physical act); from the other view the rate difference in VI as opposed to a VR is the result of the higher reinforcement rate resulting whenever higher response rates occur in a VR (a consequence contingent on a higher order assembly level of behaviors).

### 2. Paradigmatic Interpretations of the Arbitrary Stimulus or "Cue"

#### a. Conceptual Precursor: The Potentially Subtle and Elusive Nature of Controlling Stimuli

Explicitly established controlling stimuli such as those in Pavlovian procedures and discriminative procedures in Thorndikian conditioning are easy to identify. However, the controlling stimuli in simple undifferentiated Thorndikian procedures would typically be exceedingly difficult to identify. Luckily, in most cases the task in the undifferentiated case would be unnecessary because the existing general context (whatever it is) is accepted to be the controlling stimulus and typical research questions in that situation do not depend on the isolation and identification of the precise details of the necessary and sufficient controlling stimulus. Unfortunately, this leaves large gaps in our understanding of factors controlling behavior and our ability to generalize the results

#### b. A Stimulus as an Environmental Change That is Necessary and Sufficient to Control a Behavior Change i.e. A Functional Relationship

This approach is theoretically neutral and simply characterizes the events controlling behavior and how changes in the stimulus comes to control behavior changes.

#### c. Labels/Metaphors for Stimulus Control (Immediate Time Scale Adaptation or Reactions)

i. Control
ii. Elicit
iii. Educe
iv. Induce

#### d. Types of Stimuli That Could Have a Functional Relationship With a Behavior

i Explicit Stimuli
ii. The Behavior of the Organism Itself as a stimulus

##### (1) Epistemological Fine Point

Asserting that the "cause" or "explanation" for Behavior B is Behavior A may be of less value than it seems. It simply replaces the question "why Behavior B" with the question "why Behavior A"? Care must be taken to provide an informative answer rather than a facile one.

#### iii. The Passage of Time as a Stimulus

Some relationships such as fixed interval responding, can easily be shown to be under the control of time itself

### e. Sources of Variance in Stimulus Control

Some relationships can be direct or explicitly controlled like response count in an FR schedule while others can be indirect like response count in an FI schedule.

## 3. Paradigmatic Interpretations of the Subsequent Outcome

### a. Conceptual Precursor: How Reinforcement is Conceptualized Can Be Seen as a Core Concept of Behavior Analysis

Reinforcement is not "getting the idea", it is not a random act of free will, it is not space aliens making the animal do it again. What it is, is the exposure to events and functional relationships in the environment that have as a result the repetition or strengthening of a behavior. It is the semipermanent change in a behavior that emerges and is lost across the seconds to days time scale that defines reinforcement. Reinforcement is to be understood by understanding what events and functional relationship make it happen, not what brain activity, nor what thinking process, nor where the space aliens are from. Recall it was what objects and their characteristics that were considered the cause of egg retrieval not what the goose thought. To understand precisely what factors and relationships cause reinforcement to happen, and how it is generalized, could be seen as the purpose of behavior analysis.

#### i. An Interesting Historical Side Note

While researching stomach secretions, Pavlov noted that his dogs salivated to the presence of the caretaker that fed them, and even salivated to the sound of a metronome that preceded meat powder in the mouth. He described his momentous results in terms of the procedures necessary and sufficient to produce them. Food was labeled an unconditional stimulus because it would result in salivation in the absence of any preconditions. The sound of the metronome was labeled a conditional stimulus because its ability to elicit salivation was conditional on the pairing procedure.

He was, the first researchers to systematically and reliably demonstrate an instance of short time scale adaptation in non human animals. He described the cause of the adaptation as the procedures that produced it (exactly as a radical behaviorist would characterize it today). He was truly prescient.

His research was translated into English and suffered a misrepresentation into the pervasive internalism Weltanschauung of the day. The UCS became the unconditioned stimulus or the one that did not require conditioning for its occurrence, and the CS became the conditioned stimulus or the stimulus that demonstrated that the animal was conditioned by the procedure. This

alteration encouraged the inference that the procedure changed the state of the animal (i.e., the animal was "conditioned") and that that state in turn caused the behavior (i.e., the behavior occurred because the animal was "conditioned").

### b. Preeminence of the Correlation of the Subsequent Outcome with Antecedent Events in Short Time Scale Adaptation

Of all the factors that affect short time scale adaptation, by far the greatest is the relationship between the antecedent events and the subsequent outcomes. The outcome following the key peck in Thorndikian procedures or the outcome following the arbitrary stimulus in Pavlovian procedures and how that conjunction occurs accounts for the largest source of variance in short time scale organismic adaptation.

### c. Characterization of the Subsequent Outcome

The partitioning of the subsequent outcome/consequence into either a stimulus or a behavior is relatively arbitrary at the most fundamental level in that behaviors have stimulus consequences and stimuli elicit behaviors. However, conceptualizing the outcome/consequence as either one or the other is typically what is done in theorizing and does reduce the complexity of discussing the phenomenon.

#### i . Consequence / Outcome as a Stimulus

The stimulus properties of the reinforcer are thought to be the critical event.

#### ii. Consequence / Outcome as a Behavior

The behavior of consuming or behaving with respect to the reinforcer is thought to be the critical event. This was the approach taken by Premack.

### d. Manifestation of the Subsequent Outcome

#### i. Presentation of the Outcome

#### ii. Removal of the Current Condition

### e. Conceptual Precursor: Metaphors and Determining Useful Labels and graphics for Entities, Processes, and Functional Relationships Thought to Characterize Short Time Scale Adaptation

When the functional relationship we now label reinforcement was first identified, various words were used to point to or describe the effect. Each captured some of the properties of the set but none captured everything

perfectly (specified everything that was, and nothing that wasn't). The additional factors were informally added or removed as ad hoc emendations.

The known details of the functional relationships could have simply been specified as the definition of an entirely new word, but the ability to predict and generalize an effect, to some degree, stems from the informal implications of the label.

It is important to note that the various conceptualizations in the following section are not mutually exclusive and all could, in their own way, be correct. Which is to say, each captures some aspect of the process now labeled reinforcement, each provides for informal generality of the effect to something else, and each implies at least one implication that is false or at least unproven.

Given the enormous complexity of the functional relationships of reinforcement and our lack of total knowledge, there is no completely correct graphic that cannot be criticized on some grounds

### f. Metaphors/Labels for the Effect of the Subsequent Outcome

#### i. Reinforce, Strengthen, Increase, Augment, Induce

This approach to describing short time scale adaptation makes intuitive predictions that flow from the notion of a subsequent outcome causing "stronger" or more responding. Response rate and momentum would be central notions. This conceptualization is illustrated in Figure 9.8.

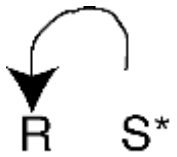



*Figure 9.8 An illustration of a subsequent outcome reinforcing or strengthening a response.*

The negative aspect of this graphic is that it could be taken to suggest that the behavior is disembodied and, at its most extreme, the behavior is equally likely in all stimulus situations. For example, it could be expected that a pigeon reinforced for pecking in a chamber would stand in a parking lot pecking furiously.

#### ii. Attach, Connect, Unite, Bind

This approach to describing short time scale adaptation makes intuitive predictions that flow from the notion of a subsequent outcome causing a response to have a higher probability during or following a stimulus. Stimulus control would be a central notion. This conceptualization is illustrated in Figure 9.9.

*Figure 9.9 An illustration of a subsequent outcome attaching or connecting a response to a stimulus.*

The negative aspect of this graphic is that it could be taken to suggest that, at its most extreme, the exact stimulus must be present or the response would not occur. For example, if a person were reinforced for opening the door in blue light, then if the light were changed to red, the person could not leave the room. Additionally, at its most extreme, the depiction could be taken to imply that only the exact response could occur. For example, if a person learned to open a door with their right hand, then when that hand was in a cast, they could not leave the room. Finally it could be taken to imply that the response was inevitable given the occurrence of the stimulus

### iii. Select, Choose

This approach to describing short time scale adaptation makes intuitive predictions that flow from the notion that a subsequent outcome causes the behavior under observation to be selected from the entire behavioral repertoire. A narrowing of the behavioral repertoire would be a central notion. This conceptualization is illustrated in Figure 9.10.

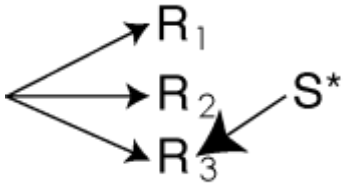



*Figure 9.10 An illustration of a subsequent outcome selecting or choosing a response out of a set.*

The negative aspect of this graphic is that it has all the flaws of the attach/connect example

### iv. Reinforce in the Presence of a Stimulus

This approach to describing short time scale adaptation makes intuitive predictions that flow from the notion of a subsequent outcome causing a response to have a higher probability during a stimulus "in whose presence " it occurred. Stimulus control would be a central notion. This conceptualization is illustrated in Figure 9.11

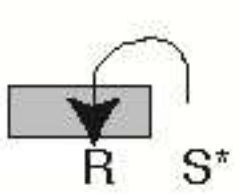



*Figure 9.11 An illustration of a subsequent outcome occurring in the presence of a stimulus*

The flaw in this description is that it simply blurs the stimulus and provides no way to predict generality before the fact. It is an attempt to finesse the dissatisfaction concerning both a connection and a disembodied rate by implying that "a response" is strengthened "in the presence of" stimulus factors and that the stimulus controls the occurrence of the response to some unspecified degree, but studiously avoids explicitly specifying that degree. Additionally, it is typically meticulously explained that the functional control of the response by the stimulus is thought to be entirely unlike the control of a UCS over a UCR, or the control of a CS over a CR, and the term "connection" is nothing short of blasphemy. An issue raised by this perspective's opponents is that stimulus control issues are covered only after the fact and that replacing an explicit implication of stimulus control with an ad hoc reference to stimulus control is unprincipled.

### v. Graphical Depictions of Events at Moment of Reinforcement

All four of the previous graphical depictions have the weakness of poorly characterizing the properties of either or both the controlling stimulus or the controlled behavior. The more complex depiction in Figure 9.12 below would provide a better framework for the properties of the stimulus control established by reinforcement. The unfortunate cost being that the depiction is cumbersome. The benefit of the figure 9.12 depiction is that it clearly implies that the precise stimulus and the precise response characteristics in effect at the moment of reinforcement are only one element of a distribution of elements across some dimension to which the effect of the reinforcer spreads to some degree. As a result, the depiction makes it clear that it would be expected that similar stimuli should function similarly and that variations in the response would occur but that that spread has a decreasing limit. An obvious flaw is that the dimensions are not explicitly characterized and surely more than two dimensions are likely to be involved.

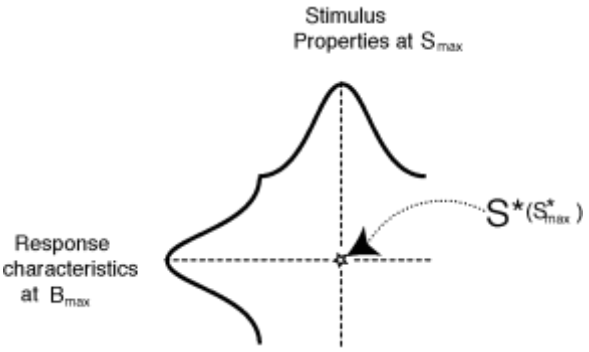



*Figure 9.12 The depiction of the reinforcement of a response in the presence of two factors: hue and the characteristics of the response. The precise hue and response properties are illustrated as orthogonally varying functions such that the details of the response properties and stimuli present at the moment of reinforcement can vary independently. Gaussian functions were arbitrarily chosen and reinforcement was presumed to occur at the mean stimulus and mean response. If a new behavior to a new stimulus were being shaped, reinforcement would be positioned toward one end of the distribution.*

The depiction in figure 9.12 could be expanded to contain three event dimensions quite easily by using a three-dimensional figure as is demonstrated in Figure 9.13 provided below. In that case, the conjunction of events on three dimensions at the moment of reinforcement could be conceptualized and a visual anchor would be available to discuss how changes in those three dimensions could affect the probability of a response. The cost being an even more cumbersome graphic.

Figure 9.13 portrays the mean response count, the mean elapsed time, and the mean explicit stimulus hue at the moment of reinforcement. Various response counts would raise or lower the horizontal response count line. Various elapsed times would shift the vertical elapsed time line right or left. Finally, changing the key color would shift the diagonal line in or out on the *z*-axis.

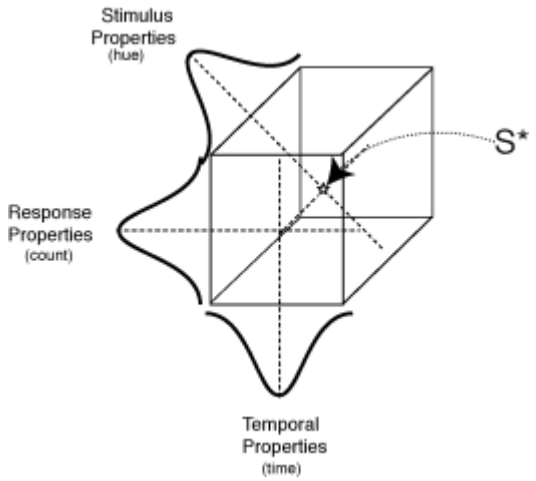



*Figure 9.13 The depiction of the reinforcement of a response in the presence of three stimuli, response count, hue, and elapsed time. The precise values of these three stimuli are shown to orthogonally vary such that a set of stimulus conjunctions are associated with the response count and would therefore be expected to probabilistically control the behavior as a function of their*

*similarity to the exact reinforced conditions via stimulus generalization along those three dimensions.*

It should be apparent that increasing the number of dimensions in a graphic will not be able to adequately capture all the complexity of the stimuli and behavior involved in reinforcement. It will always be the case that the freedom to invoke some number of ad hoc emendations will always be required. In sum, take any graphic or term as an approximation

## C. Generality of Functional Relationships Which Originated as the Result of Short-Time Scale Adaptation

The reliability of the functional relationships obtained as the result of schedules of Thorndikian and Pavlovian reinforcement is relatively high. Additionally, informally generalizing those findings into similar situations has been for the most part (but not necessarily) successful. However, a better more principled framework is needed.

### 1. Formal Principled Determination of Generality

A formal, principled system for generalizing the functional relationships established by short time scale adaptation is a work in progress. It requires rules for translating observed relationships into novel dimensions, as well as some way to quantify the spread of effect within local and known dimensions.

### 2. Generality Based on correctly intuiting an Extension into a Unique Situation

Successful generality in this case comes after the fact. The "prediction" was empirically supported. Subsequently, the proven basis for similarity can be then be used as a basis for generalizing in the future.

### 3. Generality Based on correcting a Failure to Extend into a Unique Situation

A failure to generalize correctly may lead to an insight into a functional relationship which does lead to a successful generalization. For example, data from a simultaneous discrimination was 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. The prediction was wrong because the two discriminations were controlled by different processes even though they appeared to be similar. Rather than the pairing of a simple discrete stimulus with reinforcement coming to control responding, all stimuli in the second half of an interval control increasing responding because they have an increasing correlation with the food presentation. The correction of the failure to

generalize led to the better principal: "stimuli correlated with the better half of a reinforcement gradient control responding."

#### 4. Conceptual Follow-up: 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 and the absence of that knowledge may effect generality.

Procedures enumerated below in chapter 10 examine behaviors other than terminal behavior and portions of the interreinforcement interval other than the few moments before reinforcement, in addition to the traditional factors. The expectation is that understanding behavior in addition to the operant, and portions of the immediacy of reinforcement gradient other than the few seconds preceding reinforcement will provide information which will help generalize functional relationships involving the otherwise well understood operant.

## III. Formal or Scrupulous Usage and Problematic Issues

### A. Environmental "Events" Are Actually Environmental Changes

Typically, events are discussed in this and other textbooks as if they occurred against a background of absolutely nothing. This is an oversimplification. To be scrupulously precise, there are always stimuli present, there are always behaviors occurring, and there are always systematic relationships already in effect. Most precisely, only stimulus changes occur, only behavior changes occur, and only changes in relationships occur.

### B. To "Strengthen" a Response is Actually to Increase or Maintain the Probability or Momentum of a Response Class Given a Stimulus Class

While the word "strengthen" is a metaphor, it is well understood by the behavioral cognizati. Unfortunately, its meaning and implications can be a bit opaque to a newcomer. To strengthen a response is actually to: 1) increase the probability of the behavior or increase the resistance of that behavior to disruption (i.e., momentum) from its base probability given the occurrence of a stimulus class, 2) to maintain that probability or momentum at its asymptotic value, rather than allowing the behavior to extinguish or weaken or 3) to simply increase the momentum without necessarily changing the rate.

### C. "Behavior" Actually Refers to a Behavior Change Under Stimulus Control (i.e., a Functional Relationship)

What is meant when the term "behavior" is used is not always clearly conceptualized, A behavior is not a singularity that pops into and out of existence like a disappearing balloon floating in the middle of a clear sky. A behavior is more like a particular instrument in a symphony of 100 instruments, which has become more prominent for a time. Additionally, we are typically interested in measuring a behavior given a particular stimulus class. For example, responding to the CS in Pavlovian conditioning and responding to the $S^D$ in Thorndikian conditioning. Obviously, if the controlling context (i.e., CS or $S^D$) has been inadvertently changed in an attempted replication there could be unaccountable variance in our dependent measure because we may not be presenting an effective controlling stimulus for the behavior of interest.

An especially clear exemplar of strong stimulus control is the control apparent after an explicit red green discrimination training during which pecks to green are reinforced and pecks to red are extinguished and those conditions are roughly alternated between the two conditions. While not every conditioning procedure may establish the sharp boundaries that an explicit discrimination procedure does, the controlling or contextual stimuli must always be considered in any procedure. It should be obvious that even after months of reinforcement for pecking a key in a chamber, a pigeon is unlikely to stand in the middle of a basketball court furiously pecking the air. It should be equally obvious that in many situations identifying the precise composition of the controlling stimulus (or more precisely the class of controlling stimuli) may be insurmountably difficult, and not relevant to the task at hand.

### D. Traditional, But Problematic Focus on Only Terminal Behavior or the Operant

Historically, there has been little interest in the broad range of behaviors conditioned in a situation. Rather, only the occurrence of the terminal behavior immediately preceding the reinforcer (i.e., the operant) has been of interest. While our understanding of this very important class of behavior has, as a result, been enormously advanced, that class of behavior has been removed from its larger context, and many phenomena appear anomalous while others are ignored altogether. The narrowness of focus was essential to characterizing how reinforcement affects behavior, but it now limits our ability to understand the range of behaviors and to generalize functional relationships into all contexts.

There are two classes of behavior that warrant additional research interest.

#### 1. First Remediation Strategy: Assess Terminal Behavior in <u>All</u> Portions of the Imminence of Reinforcement Gradient or Across the Entire Interreinforcer Interval

Most typically, terminal behavior is examined when it is most likely. For example, during the last portion of the interreinforcer interval. An illustration of how this focus inadequately characterizes the effects of reinforcement is given by first, establishing an FI 60-s schedule and noting that reasonably robust responding occurs 20-30 seconds prior to the reinforcer, then, changing the schedule to an FI 30-second schedule and noting that no responding occurs 20-30 seconds preceding the reinforcer. Whatever controlled behavior in the FI30-sec was not the same as in an FI 60-sec, yet the temporal distance to the reinforcer remained the same.

### 2. Second Remediation Strategy: Assess Reliable Behavior Other Than the Terminal Behavior or Operant in All Portions of the Imminence of Reinforcement Gradient or Across the Entire Interreinforcer Interval

Most typically only the class of behavior that occurs within a half a second of the reinforcer is recorded. However, very regular patterns of other behaviors occur during early portions of a fixed-interval and other schedules.

If the traditional conceptualization of the traditional "learning" task is suboptimal for some situations, then our general knowledge base is equally suboptimal. Our present focus is not only on the class of behavior to stimuli explicitly correlated with the imminent occurrence of the reinforcer (i.e., those labeled the operant) but also on the behavior to stimuli explicitly correlated with the absence of the reinforcer.

## E. Traditional, But Problematic Short Trials Methodology

In laboratory research, the point is to understand how behavior adapts with an increasing number of exposures or trials to some relatively well defined learning task. Because there is an emphasis on a relatively well defined and local effect (i.e., the operant), and on bringing the research to a conclusion relatively quickly, short trials are often used.

The net result of these procedural optimization strategies has been that the very great majority of the body of knowledge on short time scale adaptation concerns exposures of about 1 minute per trial and trials concatenated into approximately 30-50 trial sessions. An often overlooked regularity of this procedure is that the beginning of the trial is often clearly signaled as a period in which the reinforcer is virtually impossible. This methodology is de rigor even though it ignores the fact that repeated exposures to stimuli with a negative correlation with subsequent functionally important outcomes may have important effects.

### F. Traditional Disinterest in a Detailed Characterization of the Effects of Stimuli Negatively Correlated with Reinforcement

Many schedules have a signaled segment positively correlated with reinforcement and stimulus conditions negatively correlated with reinforcement. Both of these functional relationships must be addressed in formal theorizing rather than researching mostly the facilitative effect of food on terminal behavior (i.e., the operant).

### G. Insufficient Principled Conceptualizations Specifying How "Response Strength" Generalizes or Extends Across Stimulus Dimensions

Substantial research has been done on stimulus generalization gradients within stimulus dimensions but there has been less work developing a principled system with which to bridge the gap across seemingly incommensurable dimensions.

### H. Insufficient Principled Conceptualizations Specifying How Sets of Local Contingencies Can come to Function as a Global Contingency

This issue has been the cause of several controversies in the past. Whether the subject is under the control of the isolated stimulus or the relationship between the stimuli(transposition), and whether the subject has learned a response or learned to repetitively respond(partial reinforcement effect) are notable.

The following issue has been used as a research example throughout this text. For example,

1. If a red key and a green key are presented side by side where a CRF schedule is on the green key and extinction is on the red key, then pecks will occur to only the green key and no pecks will occur to the red key.
2. The same thing happens with 9 extinction colored keys and one reinforcement colored key.
3. It also happens with randomly presented colors on one key.

Each of these three functional relationships are seemingly explained by "stimuli in who's presence food occurs control responding, those stimuli that aren't paired, don't control responding".

*The problem arises with the following procedure:*

4. If the same ten different key colors are each presented in a fixed order with reinforcement available only for pecks to the final stimulus; then pecks will occur to all the stimuli in the second half of the sequence even though key pecks to those distinct colors were never reinforced.

*The solution*

It appears that the explanation for what controls responding must be adjusted. The meaning of "stimuli paired with food" changes from a distinct single stimulus paired with food to "all stimuli with a positive correlation with food presentation". The revised explanation covers both simultaneous and serial discriminations.

## I. Notable Under Researched Contingencies

The narrowness of typical research procedures poses a dilemma to serious theorizing. One could be faced with either 1) accounting for the body of existing research knowledge and possibly fail to generalize to previously unresearched parameters; or 2) accounting for a very broad range of behaviors but fail to emphasize some principles established in the existing well-researched regime of short time scale adaptation. The present tack is to theorize based on the laboratory-generated database but to also deal with aspects of the nontraditional database that is relevant to generalizing the obtained effect to a broader range of parameters. This text will give short shrift to some popular research topics

The most notable under researched contingencies are: 1) those related to the correlations of portions of the interreinforcer interval other than the few seconds preceding the reinforcer and behaviors other than the terminal behavior (i.e., other than the operant), 2) interreinforcer intervals that are in the minutes to hours time scale vs. laboratory exposure to short IRIs, 3) closed economies where animals are exposed to the contingencies 24 hours a day with no alternate context where other primary reinforcer are regularly scheduled at some other time, 4) situations containing a wide variety of substantially different contingencies intermixed versus the same single learning task or contingency repeated over and over where regularities throughout the interfood interval can become quite salient, such as concatenated trials where the post reinforcement period is correlated with the maximum separation from the upcoming reinforcer, and 5) multiple competing contingencies always present, as opposed to contingencies presented in the absence of any concurrent contingencies.

The criterion for research in a new area is the degree to which traditional explanations work in the new area. If explanatory failures occur, then research in that area is mandatory.

## J. Speculations Pertaining to Why the Outcome Functions as it Does

From a behavioral perspective the following inferences are irrelevant, however they do surface frequently in informal discussions.

### 1. Inferred Internal Homeostatic Processes

The general term for this type of causal factor underlying reinforcement is "tension reduction."

#### a. Inferred Optimization of Drive or Need State

This effect is thought to provide the internal physiological cause of the strengthening or connection caused by the subsequent functionally significant event. This approach to explaining short time scale adaptation makes intuitive predictions that flow from the notion that the reinforcer reduces some aversive general motivational state such as hunger.

#### b. Inferred Optimization of an Internal State by Preparation for Consummation

This effect is thought to provide the internal physiological cause of the strengthening or connection caused by the subsequent functionally significant outcome. This approach to explaining short time scale adaptation makes intuitive predictions that flow from the notion that an antecedent behavior prepares the organism for the subsequent event and makes it more reinforcing or less aversive such as anticipatory salivation when meat powder is the outcome or tensing before the occurrence of electric shock. The resulting antecedent behavior could be labeled a preparatory response in the presence of the stimulus context.

### 2. Inferred Optimization of the Timing of Induced Behavior

It could be argued that any event that induces, elicits, requires, or even simply controls a behavioral adjustment or adaptation of any kind for any reason will function to cause short time scale adaptation. That is to say that any behavioral adjustment or adaptation induced by an event at time *t* will condition a behavior (e.g., a CR) to any stimulus that regularly precedes that subsequent outcome at time *t-1*. Often the behavior conditioned at *t-1* is the same behavior that occurs at *t*. The prototypical example is that a bell preceding meat powder will cause salivation to the bell.

This behavior adjustment conceptualization easily handles higher-order conditioning and conditioned reinforcement because in those cases the behavioral adjustment at time *t* just so happens to be a learned behavior rather than an unconditioned one. In either case, the production of a UR or CR is seen as the cause of the preceding CS coming to produce a CR at time *t-1*. No internal process need be considered.

This approach could be considered a functional approach because it specifies nothing more than if a behavioral adjustment or adaptation (eg. UCR) occurs to a stimulus, then a CR will be conditioned to the antecedent stimulus if one does not already occur.

In the absence of measured induced behaviors and a systematic way to predict the details of the resulting behaviors to the antecedent stimuli, this approach cannot be used as an explanation for why reinforcers work in that all of its properties are inferred after the fact.

# IV. Detailed Presentation of the Functional Relationships Involved in Short Time Scale Adaptation

The prevailing interest of EAB is in revealing the specific environmental relationships that produce or maintain short time scale behavioral adaptation. In particular, the functional relationship between stimuli, responses, and subsequent outcomes which produce the acquired functional relationships between stimuli and responses which emerge and are lost across the seconds-to-days time scale (as is illustrated in Figure 9.2).

It is important to emphasize that our focus on developing a principled explanation for those causal and acquired functional relationships between inputs and outputs rather than simply cataloging the lists of stimulus response relationships that result in some short time scale adaptation. The task is to develop the smallest set of general laws and their principled derivatives that account for the broadest range of behaviors in the broadest range of situations possible.

## A. Conceptual Review: The Preeminence of Ontogenic Contingency History in Understanding Short Time Scale Behavioral Adaptation

From a behavior analytic perspective, virtually everything that makes an individual member of a species unique is the result of that organism's ontogenic history of specific contingencies of Thorndikian or Pavlovian reinforcement (i.e., "schedules of reinforcement").

Recall that EAB is focused on understanding the moment-to-moment changes in an individual organism's semi-permanent adaptation to covariance in the environment that emerges across the second-to-days time scale or short-time scale adaptation (also known as learning or conditioning).

## B. Conceptual Review: Understanding the Emergence or Acquisition of Short Time Scale Adaptation

The measure of learning is the transition in a behavior considered a zero state to some asymptotic performance to a different situation. For example, if one time when your dog ran up to you and stood on its hind legs you gave your

dog a treat, and you continued this reinforcement contingency for several weeks. You would see an increase in standing on hind legs. In fact the dog would continue for a short time to stand even after you quit giving it treats. This effect is called "learning" and depends on the number of exposures to the learning task or "trials". Learning is illustrated in Figure 9.14 and documents the resulting change in stimulus control (dog standing when around you) with increasing experience with that new procedure (y-axis change as a function of x-axis change). This issue was first presented with Figure 1.18. To reiterate, the figure does not illustrate simply the physical act of "standing", rather it is a function depicting the learning to stand when around you.

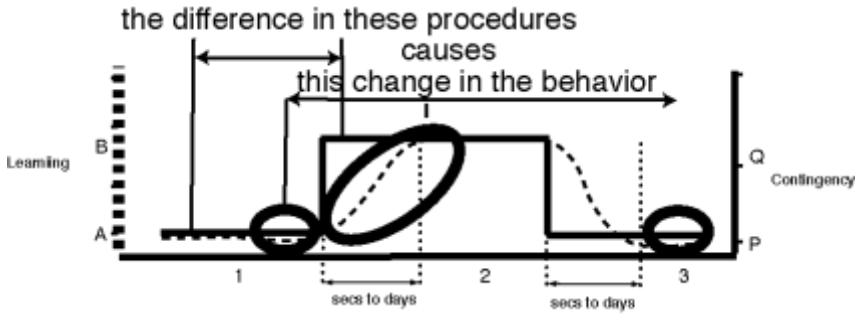



*Figure 9.14 This figure is a re-presentation of Figure. 1.18. This figure depicts the emergence or acquisition in a dependent variable (dotted line) as a function of a change in the independent variable (solid line). In sum, the change or difference in the dependent measure is caused by the difference 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.*

### C. A Stimulus Reinforcer Correlation or a Pavlovian Contingency

These procedures have a correlation between the occurrence of an arbitrary stimulus such as a bell and the occurrence of a functionally significant event such as meat powder in the mouth. The organism is repeatedly exposed to this correlation in a series of trials. A change in the frequency of a behavior related to the unconditioned response to the reinforcer comes to occur to the antecedent neutral stimulus. For example, if meat powder follows a bell then the bell comes to control salivation. Various classes of Pavlovian contingencies have orderly classes of effects. The core procedure and resulting behavior change are illustrated in Figure 9.15.

If we randomly present amber and blue lights for a day and watch what a dog does, we will find that after a short time, the dog will do nothing. It will behave the same before, during, and after either light. Suppose we squirt meat powder into the dog's mouth every so often, after a short time we will find that the dog will behave the same most of the time but immediately after the meat powder squirt, the dog will salivate (as it did the first time it received the meat powder squirt). So far we have shown that the amber and blue lights are neutral and that the meat powder elicits salivation (the meat powder eliciting an innate reaction of salivation is labeled a reflex).

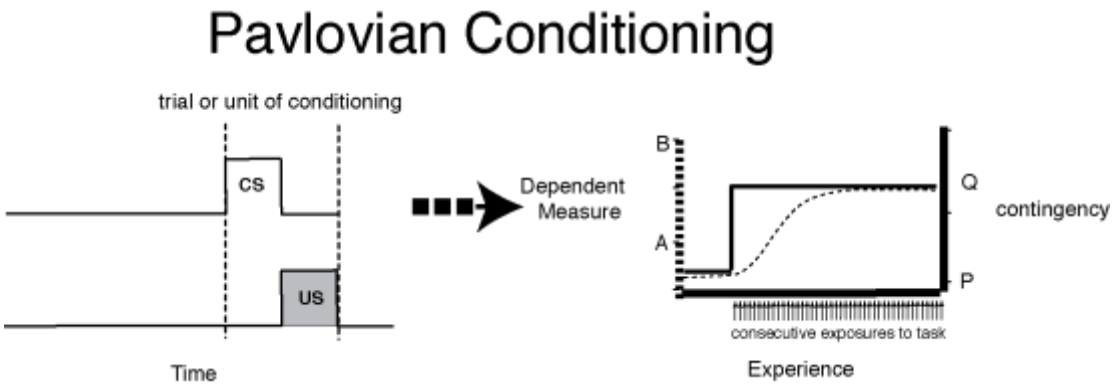



*Figure 9.15 A traditional illustration of Pavlovian conditioning. The left section of the figure depicts a Pavlovian training procedure. A CS is followed by a US. The right portion of the figure illustrates that with many experiences of the Pavlovian contingency or learning task or trial, the probability of the dependent measure given the CS increases in probability to an asymptotic level. Note that each arrow below the x-axis in the right frame designates the occurrence of a trial containing a CS US pairing.*

If we now do nothing whenever a blue light is presented but squirt meat powder into the dog's mouth every time the amber light is presented for a number of trials, we will discover **we can fundamentally change the behavioral repertoire of the dog.** Now even if we have no meat powder left, whenever we present the amber light the dog salivates (at least initially). But every time we present the blue light, the dog does nothing. The dog has exhibited a semi-permanent change in its reaction to events in the environment; **it has learned**. It is important to note that the dependent variable is not simply salivation, but rather learning to salivate to a stimulus that had not previously controlled salivation (i.e., the amber light). It is an ontogenically acquired functional relationship. This procedure has been labeled reflex conditioning, classical conditioning, respondent conditioning, or Pavlovian conditioning. The step-by-step procedures and results of Pavlovian conditioning are illustrated in Figures 9.15, 9.16, and 9.17. By any name, it is amazing. Trash cans and trees will never do it and dogs and humans will always do it. The challenge is to precisely characterize the procedures that make it happen, and to be able to predict when conditioning will and will not occur.

### 1. Specific Instantiations of Pavlovian Conditioning

In a context of blue light and no food presentations, the following procedures could be implemented.

#### a. Simplistic Trial-by-Trial Example of Pavlovian Conditioning

Figure 9.16 can be seen as a more detailed version of the procedure and results illustrated in Figure 9.15. Note that as is indicated on the right edge of Figure 9.16, the functional relationship controlled by the amber light was changed from the organism simply standing there doing nothing to the

organism salivating to the amber light. This change in functional relationships occurred as the result of the organism having been exposed to the contingency between amber light and food in Phase 2. What was initially a neutral or "irrelevant" stimulus (top portion labeled baseline in Phase 1) now reliably and semi-permanently controls a behavior (bottom portion labeled test in Phase 3) even though the two procedures are identical This change in the behavior to the amber light occurs as the result of the exposure to many occurrences of the neutral stimulus presentation paired with the significant subsequent outcome.

It is critical to note that on the first trial of the test phase no food is provided yet the behavior of salivation occurs anyhow. This is the meaning of the semi-permanent behavior change and is the continuance of the high rate of the dependent variable in Phase 3 after the contingency is removed in Figure 9.2.

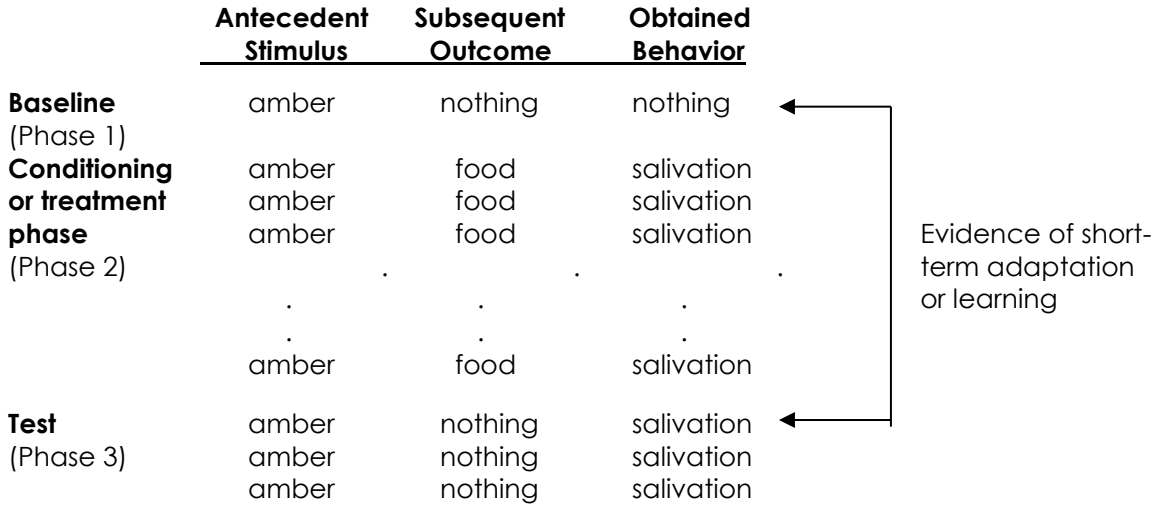



*Figure 9.16 A simplistic illustration that as the result of pairing amber and food presentation, amber by itself comes to elicit salivation. Initially during the baseline, before treatment, the amber light elicits nothing. Following amber food pairings during the conditioning procedure the presentation of the amber light controls salivation even when no food follows the light. This test condition is exactly the same as the initial baseline test when amber had not elicited anything.*

### b. More Complete Phase-by-Phase Example of Pavlovian Conditioning

Figure 9.17 can be seen as an even more detailed and complete depiction of the information illustrated in Figure 9.15. Note that as is indicated on the right edge of Figure 9.17, the functional relationship controlled by the amber light changes as the result of the experienced correlation. What was initially a neutral or "irrelevant" stimulus now reliably and semi-permanently controls a behavior.

Figure 9.17 is an illustration of a specific instantiation of Pavlovian conditioning. The left portion of each row depicts the procedure to which the animal is exposed as a 2x2 contingency table. The next two columns provide the

antecedent stimulus and the subsequent outcomes specified in the contingency table. The fourth column provides the test stimulus and the fifth column provides the resulting behavior to the test stimulus. The top or fifth row (labeled baseline) shows no reaction when the amber stimulus is first presented. Following the treatment in the fourth) (initial treatment) and third (asymptotic treatment) row in which amber preceded food and blue preceded no food, the second row (initial extinction) shows the amber stimulus elicits salivation even when no food is presented. This is the meaning of semipermanent illustrated in figure 9.2 After extended extinction, amber no longer controls salivation as illustrated in the first row.

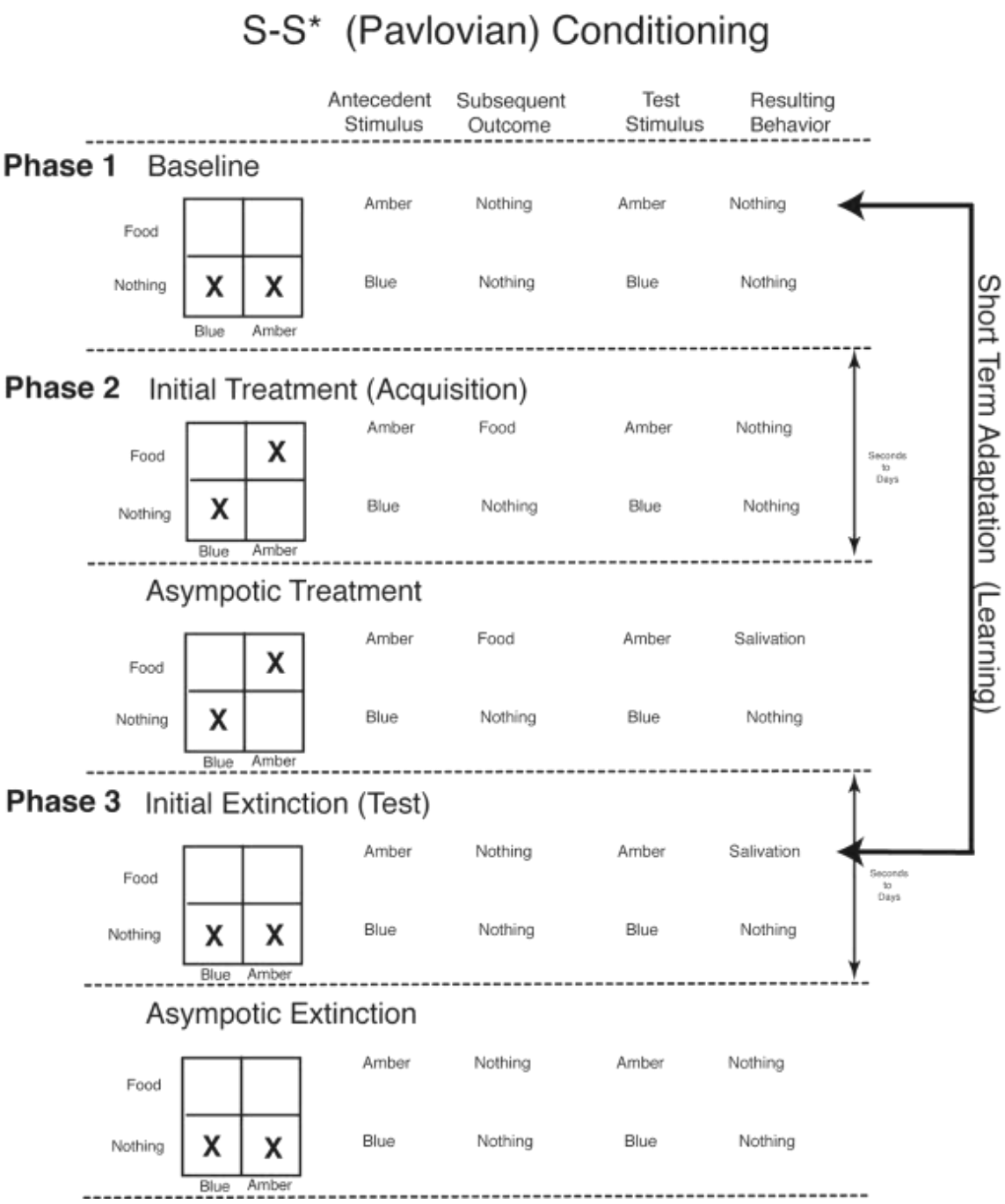



*Figure 9.17 An illustration of a specific instantiation of Pavlovian conditioning. The left portion of each row depicts the procedure to which the animal is exposed as a 2x2 contingency table. The next two columns provide the antecedent stimulus and the subsequent outcomes specified in the contingency table. The fourth column provides the test stimulus and the fifth column provides the resulting behavior to the test stimulus. The top or fifth row (labeled baseline) shows no reaction when the amber stimulus is first presented. Following the treatment in the fourth row (labeled initial treatment) and third (asymptotic treatment) row in which amber preceded food and blue preceded no food, the second row (initial extinction) shows the amber stimulus elicits salivation even when no food is presented. After extended extinction, amber no longer controls salivation as illustrated in the first row.*

### D. A Response Reinforcer Correlation or a Thorndikian Contingency

These procedures have a correlation between the occurrence of a response and the occurrence of a functionally significant event such as food presentation. The behavior shows short time scale hysteresis across successive exposures (or trials) to this correlation. For example, if food presentation comes to follow key pecks, then the rate of key pecking will increase and will semi-permanently endure even under extinction. The core procedure and obtained change in behavior are illustrated in Figure 9.18. Various classes of Thorndikian contingencies have orderly classes of effects.

If we randomly present an amber and blue light to a pigeon and watch what it does, we will find that after a short time, it does nothing. It will behave the same way before, during, and after either light. If we watch the pigeon and record all the various things it does such as turn, wing flap, step, bend its head down, etc., we will notice that they each have some rate of occurrence that remains stable day after day and that rate is the same regardless of whether the light is amber, blue, or nothing. Suppose we present food to the pigeon at totally random times and again watch what the bird does, we would find that the bird eats during the food presentation but otherwise does the same thing before and after the food presentation.

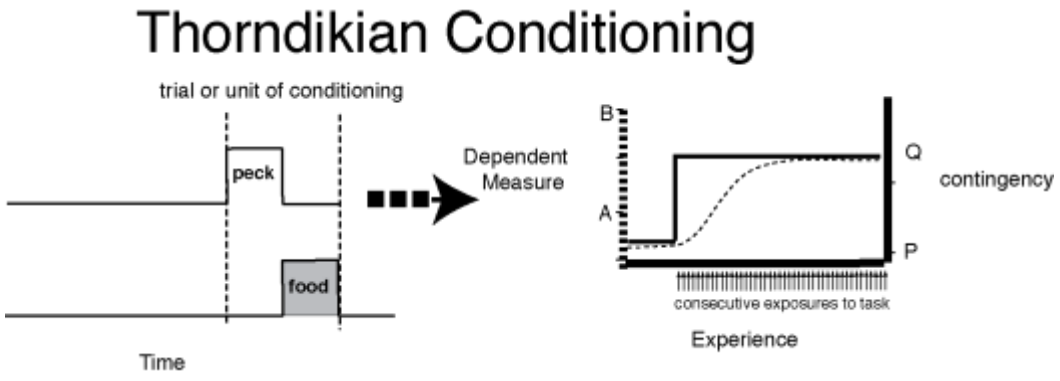



*Figure 9.18 A traditional illustration of Thorndikian conditioning. The left portion of the figure depicts a Thorndikian training procedure. Pecks are followed with food presentation. The right portion of the figure illustrates that with many experiences with the Thorndikian contingency learning task or trial, the dependent measure increases in probability up to an asymptotic limit. Note that each arrow below the x-axis in the right frame designates the occurrence of a trial containing a peck food pairing.*

Now that we have established the baseline behaviors associated with each of the events. We can proceed to the next step. Suppose we choose an arbitrary behavior such as pecking and whenever the amber light is on, we follow pecking with food presentation on a number of occasions. We never follow pecks with food in the presence of the blue light. We never present food after any other behavior. As a result of this procedure, we have **fundamentally changed the behavioral repertoire of a living organism.** Now each time we turn on the blue light, the bird carries on normally and each time we turn on the amber

light, the bird pecks the key furiously, in fact, even if we no longer give it food for pecking (at least initially) it will peck. The pigeon has exhibited short time scale adaptation or has learned to peck an amber key. This procedure has been labeled operant conditioning, instrumental condition, trial and error learning, or Thorndikian conditioning. The procedures and results of Thorndikian conditioning are illustrated in a step-by-step procedure in Figures 9.18, 9.19 and 9.20. By any name, it is amazing. Trash cans and trees will never do it and dogs and humans will always do it. The challenge is to precisely characterize the procedures that make it happen, and to be able to predict when conditioning will and will not occur.

### 1. Specific Instantiations of Thorndikian Conditioning

In a context of amber light and no pecking and no food presentations, the following procedures could be implemented.

#### a. Simplistic Trial-by-Trial Example of Thorndikian Conditioning

Note that as is indicated on the right edge of figure 9.19, the functional relationship controlled by the context was changed from the organism simply standing there doing nothing (top portion labeled baseline) to the organism pecking as the result of the contingencies between key pecking and food even though food does not follow key pecks (bottom portion labeled test). While the bird had done very little pecking in its initial exposure to the context, it has now come to reliably peck even though the two procedures are identical.

| | Stimulus Context | Antecedent Behavior | Subsequent Outcome | Obtained Behavior | |
|---|---|---|---|---|---|
| **Baseline** Phase 1 | amber | nothing | nothing | nothing | |
| **Conditioning or treatment phase** Phase 2 | amber | nothing | nothing | nothing | |
| | amber | look | food | look | |
| | amber | peck | food | peck | Evidence of short-term adaptation or learning |
| | . | . | . | | |
| | . | . | . | | |
| | . | . | . | | |
| | amber | peck | food | peck | |
| **Test** Phase 3 | amber | peck | nothing | peck | |
| | amber | peck | nothing | peck | |
| | amber | nothing | nothing | nothing | |

*Figure 9.19 A simplistic illustration that as the result of following a behavior with food presentation, the behavior increases in rate. Initially during the baseline, before the conditioning procedure, the amber light controls no pecking. When key pecks are followed by food presentation, amber comes to control key pecking even when food no longer follows those key pecks.*

It is critical to note that on the first trial of the test phase no food is provided yet the behavior of pecking occurs anyhow. This is the meaning of a semi-permanent behavior change and is the continuance of the high probability or rate of the dependent variable after the contingency is removed in Figure 9.2.

### b. More Complete Phase-by Phase Example of Thorndikian Conditioning

Note that as is indicated on the right edge of the figure, the functional relationship controlled by the context has changed as the result of the experienced correlation. While the bird initially had done very little pecking in the context (top row or row 5), it has now come to reliably peck (row 2).

Figure 9.20 is an illustration of a specific instantiation of Thorndikian conditioning. The left portion of each row depicts the procedure to which the animal is exposed as a 2 x 2 contingency table. The next two columns provide the antecedent behavior and subsequent outcomes specified in the contingency table for that row. The fourth column designates the two test stimuli for each row and provides: the amber test stimulus that was in effect when the peck food conjunction occurred, as well as the blue background that was in effect when nothing was reinforced (extinction). The fifth column provides the behavior controlled by the amber trial stimulus as well as the behavior controlled by the blue extinction stimulus.

The top or fifth row labeled baseline shows no reaction when the amber stimulus is first presented. Following the conditioning procedure in which key pecks are reinforced in amber (rows labeled initial and asymptotic treatment), amber can be seen to control key pecking. During the initial extinction procedure even when food no longer follows those pecks, key pecking occurs to amber. After extended exposure to extinction, responding to amber has ceased.

It is critical to note that on the first trials of the test phase no food is provided yet the behavior of pecking occurs anyhow. This is the meaning of the semi-permanent behavior change and is the continuance of the high rate of the dependent variable after the contingency is removed in Figure 9.2.

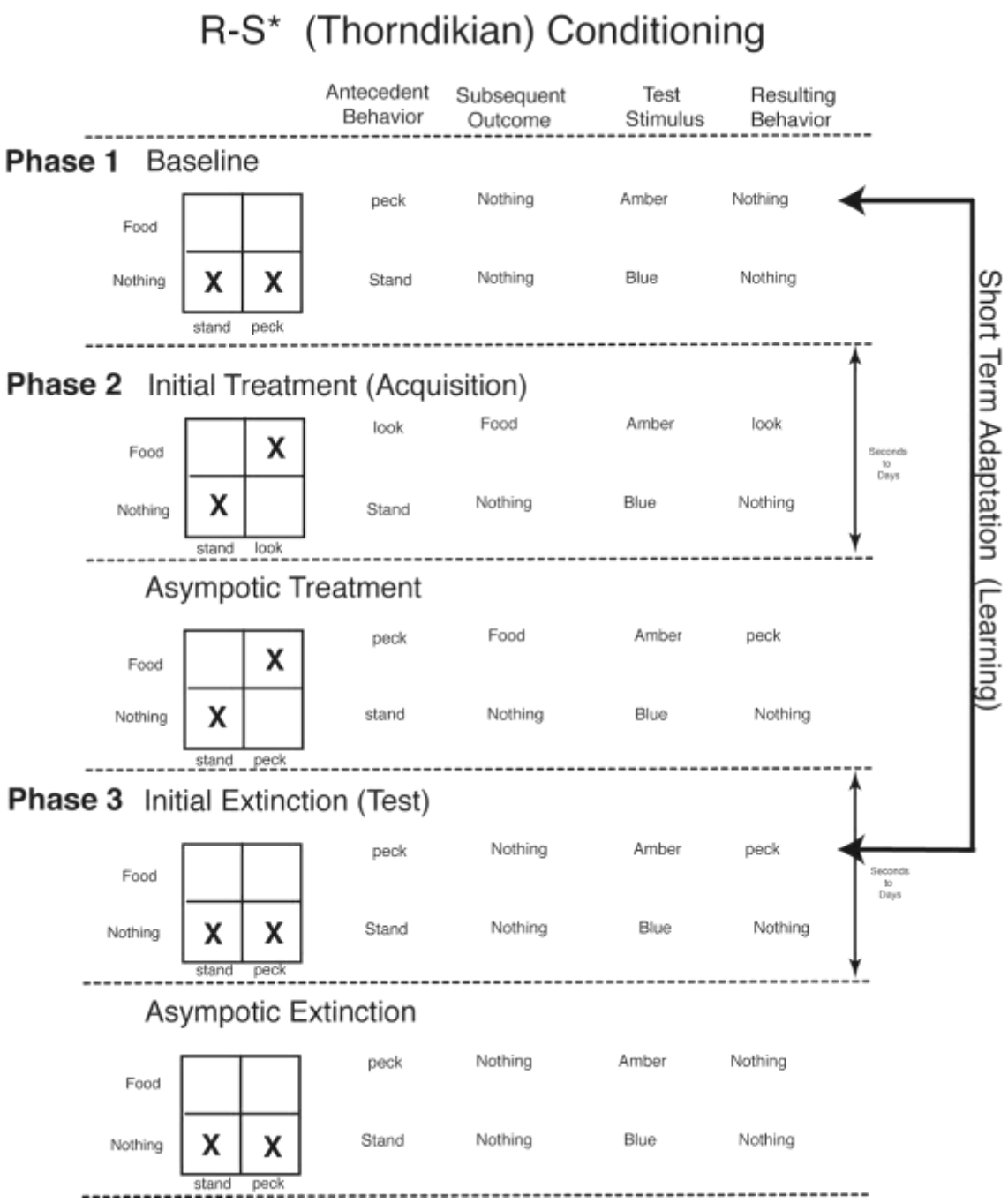



*Figure 9.20 An illustration of a specific instantiation of Thorndikian conditioning. The left portion of each row depicts the procedure to which the animal is exposed as a 2x2 contingency table. The next two columns provide the antecedent behavior and subsequent outcomes specified in the contingency table. The fourth column provides the test stimulus that was in effect when the peck food conjunction occurred (amber) and the stimulus when no subsequent reinforcer occurred (blue). It is presented as a test stimulus to see what behavior if any it controls. The top or fifth row labeled baseline shows no reaction when the amber stimulus is first presented. Following the conditioning procedure in which key pecks are reinforced (rows labeled initial and asymptotic treatment), amber can be seen to control key pecking and also during the initial extinction procedure even when no food no longer follows those pecks. After extended exposure to extinction, responding to amber has ceased.*

## E. Conceptual Follow-Up: Diversity of Presumed Relationships Between Thorndikian and Pavlovian Conditioning

Short time scale adaptation has traditionally been partitioned into Thorndikian conditioning and Pavlovian conditioning under the variety of labels previously mentioned.

Procedures resulting in Thorndikian and Pavlovian conditioning can be easily separated. Typically, in Thorndikian procedures a consequence is dependent on a voluntary behavior such as food presentation following a key peck. In Pavlovian procedures, a consequence is dependent on an explicit stimulus such as food presentation following a bell. The dependent measures in the two procedures are also simple to separate. In Thorndikian procedures, the behavior preceding food presentation increases in rate. In Pavlovian procedures, a behavior related to the behavior that previously occurred to the US now also occurs to the bell. Two different explanatory frameworks have evolved to account for the behavior changes which emerge as the result of these two different procedures.

Thorndikian conditioning procedures implement different outcomes as a function of different antecedent behaviors. Typically, as a side effect, there are different antecedent stimuli correlated with the different outcomes. Pavlovian conditioning procedures implement different outcomes as a function of different antecedent stimuli, typically as a side effect, there are different antecedent behaviors correlated with the different outcomes. As a result of either procedure, a behavior comes under stimulus control. A detailed comparison of the functional properties of each contingency across a wide variety of situations is required to determine if the characteristics of short time scale adaptation is the same in each case. At present, the terms Thorndikian conditioning and Pavlovian conditioning serve to differentiate theoretical orientation or procedural paradigms more than differentiate known and understood processes.

It is not entirely clear whether a strong distinction between Pavlovian and Thorndikian conditioning is optimal. It is interesting to note that all possible versions of theorizing about the relationship of Thorndikian and Pavlovian conditioning with respect to underlying processes have been advanced at one time or another by one theorist or another.

### 1. Thorndikian and Pavlovian Conditioning are Totally Different

Skinner is believed to have opined that Thorndikian conditioning and Pavlovian conditioning were entirely different: 1) following different laws, 2) operating on entirely different physiological structures, and 3) were entirely incompatible. No operant could be conditioned via Pavlovian procedures and no respondent (e.g., reflex behavior) was susceptible to Thorndikian procedures.

### 2. Thorndikian and Pavlovian Conditioning are Totally the Same

Donahoe has opined that both Thorndikian conditioning and Pavlovian conditioning occur with the procedures typical of either of the two paradigms and the only thing that differs is biasing factors in the schedule of reinforcement the subjects are exposed to and where the researcher looks for a dependent measure. It is not clear whether this can be taken to indicate that the two processes are the same or that the two processes are inseparable.

### 3. All Short Time Scale Adaptation is Via S-S* Contingencies

Spence asserted that both Thorndikian and Pavlovian conditioning were via stimulus pairing (often labeled Pavlovian conditioning).

### 4. All Short Time Scale Adaptation is Via R-S* Contingencies

Hull believed that both Thorndikian and Pavlovian conditioning were via response reinforcement contingencies (often labeled Thorndikian conditioning).

### 5. Functional Approach: There Are Procedures That Cause Short Time Scale Adaptation

Procedures that cause specific functional relationships such as pecking an amber light or salivating to a bell should not be taken to necessarily demonstrate two fundamentally different types of short time scale adaptation.

The conceptualization of the functional relationships emerging from procedures should follow the obtained data and theoretical context. This view argues that results from procedures, are what they are, and the decision to label them with the same or different words must flow from similarities or differences in the important dimensions of the data rather than on inferred internalisms. Additionally, the theoretical conceptualization must also follow the data. The usage of the terms cannot inappropriately group different functional relationships and cannot separate similar functional relationships. Whether Pavlovian and Thorndikian conditioning are best seen as intrinsically and fundamentally indivisible or different is an empirical question that has not yet been resolved.

## F. A Stimulus Controlling a Response or Stimulus Control

Stimulus control per se refers to the covariance of behavior with an explicit stimulus change such as responding to a green light but not responding to a red light or a dog salivating to a bell but not to a door slam. Stimulus control is an immediate term effect because **it is a reaction to a stimulus and is independent of the procedures used to establish it**. The origin of the functional relationship of a behavior change to a stimulus change (i.e., its emergence) could even be an evolutionary adaptation, rather than short time scale adaptation, for example, an eye blink to a puff of air.

Short time scale adaptation is the production of stimulus control by the ontogenic contingencies of reinforcement (either Pavlovian or Thorndikian). The issue of importance to EAB is: 1) how to characterize the environmental history which created the stimulus control [what made the learning occur]; 2) how that stimulus control varies as a function of increasing experience [its emergence across a second-to-days time scale or the shape of the learning curve]; 3) how that stimulus control varies as a function of the probability or imminence of the functionally significant event that created it. [often across the interval from one reinforcer to the next, such as the rate increase across a fixed interval or across a trial stimulus]; and finally, 4) factors controlling how it generalizes [that is to say how the behavior changes as a function of changes in the stimuli].

Evolutionarily established stimulus control is basically irrelevant for the generality of the effect to EAB. However, ontogenically established stimulus control is the major focus of EAB. In the same way the sight of food and the absence of food can be seen to phylogenically control approach and avoidance; stimuli ontogenically associated with food and its absence control analogous behaviors.

## 1. Conceptual Precursor: A Figure Simultaneously Exemplifying the Emergence and the Asymptotic Expression of Stimulus Control for both terminal and other Behavior in Each Portion of the Imminence of Reinforcer Gradient

Figure 9.21 portrays the behavior to each portion of a fixed time schedule with increasing experience.

The three dimensional surface portions of the figure are the main portion of the figure and illustrate an example of stimulus control across the two most frequently used axes in behavior analysis; 1) amount of experience (z-axis-in and out), and 2) position in an interreinforcer interval or the imminence of reinforcer gradient (x axis-left and right). Additionally, 3) this figure can also depict two different behavior vectors (e.g., approach or avoidance- y axis up or down) for the dependent variable at each point on each of those two axes.

It is important to develop the skill to read and benefit from this type of complex graphic because it enables the conceptualization of complex behavior change as a function of two simultaneous interacting causes. The natural world rarely delivers behavior change as a function of one factor at a time.

The meaning of the obtained result indicated in this figure will be elaborated later. For now, simply see it as a hypothetical example of normalized behavior change across two simultaneous dimensions (**experience and the relative imminence of food**). The data are normalized or depicted as a percent of total so that changes as a function of position in the interreinforer interval are directly comparable between the first and second half of the IRI.

The two different perspectives of the graphic are to help you see how experience is depicted across the z-axis. The upper portion of the figure within the dashed box depicts experience with consecutive trials from left to right in a

traditional two dimensional fashion. The behavior in each of 35 consecutive trials is depicted from left to right The upper line indicates the occurrence of consecutive reinforcers in time with vertical lines labeled S* (for instance food presentations every 60 seconds for 35 trials). The obtained behavior is indicated on the y-axis. It depicts degrees of approach. The data obtained for every fifth trial is also depicted within the dashed box, on the lower right to left x-axis. It is simply an enlarged version of the upper function so that the change within each trial and across increasing experience can be seen.

The three dimensional surface depiction of this data is simply positioning the data for consecutive trials behind one another rather than stringing them out from left to right as they are within the dashed box.

The first exposure to the learning task or trial is depicted in the surface plot from the front left across to the front right along the first left to right line on both of the three-dimensional surfaces. Food presentation occurs following this (and each subsequent 60-second trial). The second left to right line represents the behavior in the second trial, the third line is the third trial, and so on. The first few trials have no change on the y-axis and indicate no change in the dependent measure early in the experience. For the next few trials, the rate to the final portion of the trial increases more and more and that increase occurs earlier in the interval with increasing experience. At the same time the behavior to the initial portion of the trial begins to go in a different direction and that class of behavior then extends further into the interval with increasing experience. This trend in the behavior at the start and end of the interreinforcer interval continues until the behavior change across the interval is ogival at asymptote. This is the behavior across the last trial of the example and is portrayed at the rear of both 3-dimensional surfaces.

To review, Figure 9.21 depicts normalized responding in a series of 60-second trials that are depicted one behind the other, back the *z*-axis labeled "experience." As experience increases (back the *z*-axis), the behavior comes to drop or become more negative at the beginning of the 60-second interval, and comes to increase or become more positive at the end of the trial when food occurs.

At this point the labels are of no importance, but The beginning of each trial (when no reinforcers are likely) is labeled $S_{min}$ and $S^*_{min}$ while the end of each trial when food is presented is labeled $S_{max}$ and $S^*_{max.}$ The $S^*_{min}$ and $S^*_{max}$ designates the probability of food, while $S_{min}$ and $S_{max}$ are the labels for the stimuli associated with those probabilities of food. The labels $B_{min}$ and $B_{max}$ refer to avoidance and approach behavior.

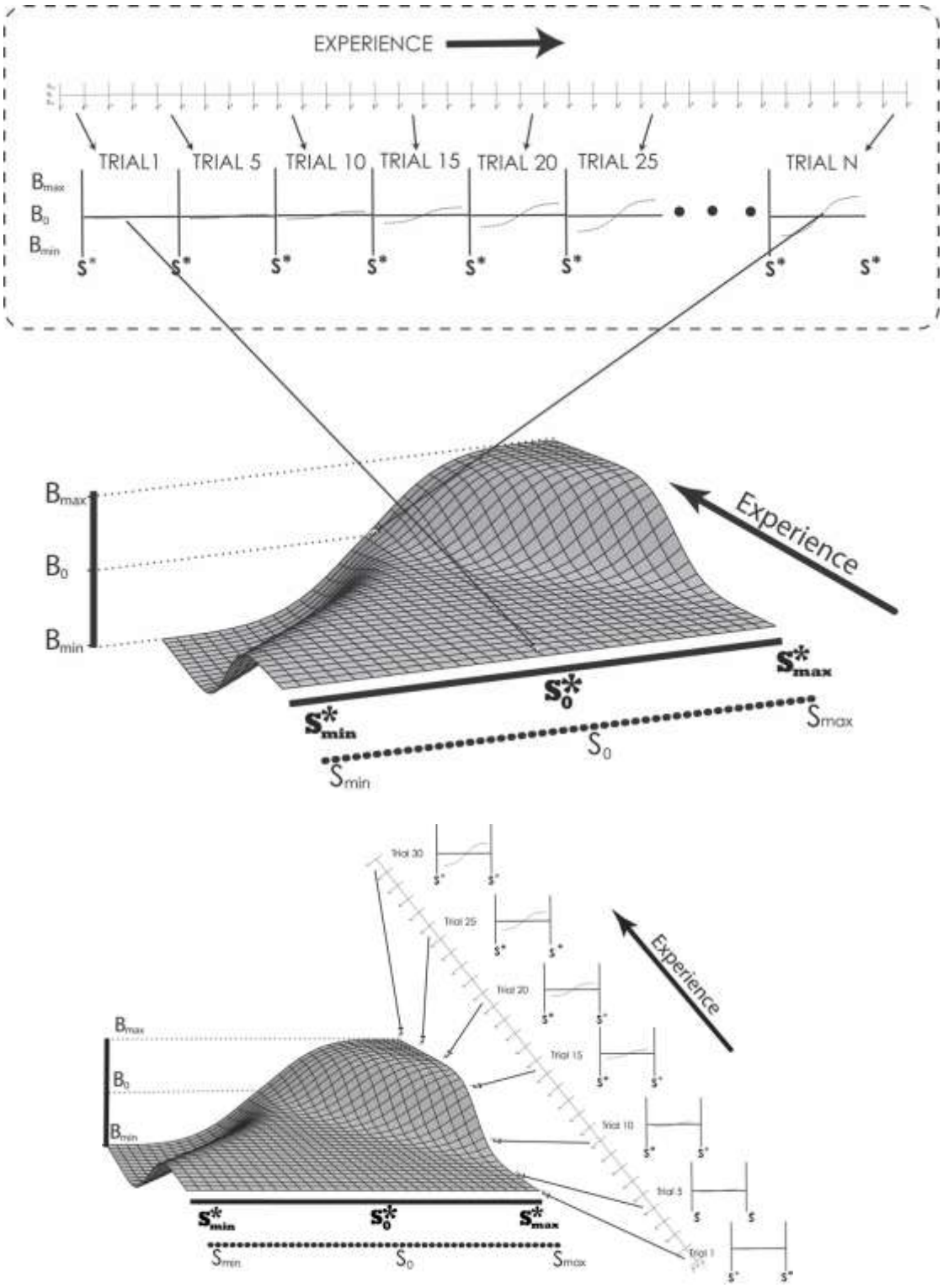



*Figure 9.21 The obtained results in each of the 30 trials given in the lower portion of the dashed box are repositioned one behind the other to form the three-dimensional figures. The data from each consecutive trial are presented in this 3-dimensional surface. As can be seen, the behavior in the earlier portion of the interval changes in a different way from the behavior at the end of the interval over the course of the 30 trials of experience. On the first exposure to the contingency no behavior occurs (the first horizontal line of the three-dimension figures. After 30 trials, the behavior goes down at the trial onset and up at the end of the trial.*

### a. Parceling Out the Emergence and Asymptotic Expression of Terminal Behavior and Behavior Across the Entire Interreinforcer Interval

Figure 9.22 depict the three-dimensional surface in Figure 9.21 and illustrate various dimensions important to short time scale adaptation, It emphasizes two aspects of behavior (emergence and asymptotic expression) in the right and left column, and simultaneously emphasizes two classes of behavior (terminal behavior and across the entire interreinforcer interval) in the upper and lower row. Most graphical depictions do not provide for both types of information. The accent dark line indicates the terminal behavior in the upper row while the bottom two frames accent the entire interreinforcer interval. The left two frames accent the emergence of the adaptation while the right two frames accent asymptotic expression.

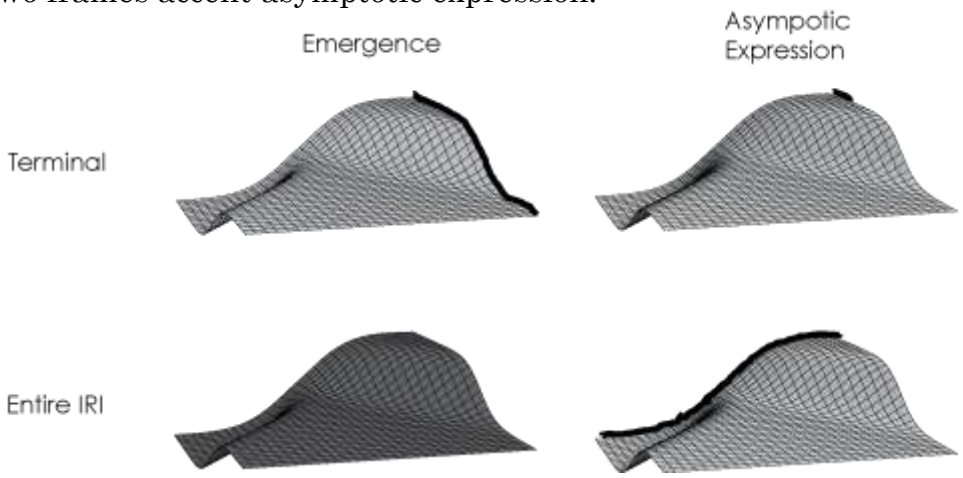



*Figure 9.22 This figure accents the emergence and asymptotic expression of terminal behavior (top row), and the emergence and asymptotic expression of the behavior across the entire interreinforcer interval (bottom row).*

#### i. The Emergence of Terminal Behavior

Figure 9.22 accents the emergence of terminal behavior in the upper left frame. This figure is re-presented in Figure 9.23. This is the classic learning curve for an operant. It shows the asymptotic increase in the dependent measure as a function of increasing experience with the conditioning procedures. The heavy line depicts a change in the rate of behavior occurring immediately preceding reinforcement. This heavy function is also the defining property of short time scale adaptation, first presented in figure 1.5 and 1.18 and re-presented in figure 9.2 and 9.4. This measure is the information presented in the right portion of Figure 9.15 and 9.18.

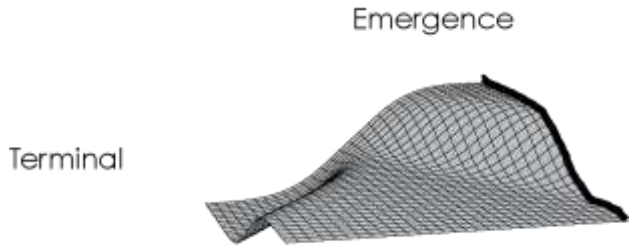



*Figure 9.23 This figure portrays the change in terminal behavior with experience. It is the information accented in the upper left frame of Figure 9.22 and the right portion of Figures 9.15 and 9.18.*

### ii. The Asymptotic Expression of Terminal Behavior

In some cases, only the asymptotic rate of the terminal behavior or the operant under some specified procedure is relevant. The indirect method of assessing short time scale adaption effects is based on this measure (Figure 1.19 and 9.5). Prototypically, the difference in asymptotic rates to two procedures is attributed to the difference in those two procedures. The asymptotic portion of a typical terminal behavior is accented in the upper right portion of Figure 9.24.

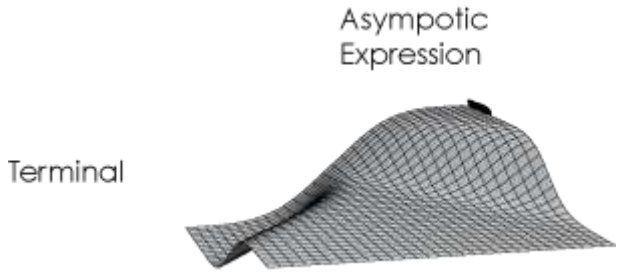



*Figure 9.24 This figure accents the equilibrium or asymptotic portion of the emergence of terminal behavior. This information was accented in the upper right of Figure 9.22*

#### (1) Behavior Analytic Terminology for the Emergence and Asymptotic Expression of Stimulus Control Over Terminal Behavior Across the Experience Axis

Figure 9.25 illustrates the labels traditionally associated with the emergence or expression of short time scale adaptation of terminal behavior or the operant as a function of experience that is due to changes in reinforcement contingencies. Revisit Figure 9.21 and note the terminal behavior as a function of the interreinforcer interval (expression), and as a function of training experience (emergence). The operant of EAB is this “terminal” behavior or the behavior immediately before the occurrence of the reinforcer.

As is illustrated in figure 9.25 transition states in adaptation are labeled "acquisition" when the initial state is baseline, and "extinction" when the final state is the baseline condition. The ease with which, or the degree to which, the

*y* measure changes as a function of experience with a reinforcement contingency, indexes the resistance to change or "momentum" of the behavior.

Equilibrium states are labeled "asymptote" when the behavior is at equilibrium with some treatment condition. The term "baseline" is most typically applied to the behavior equilibrium obtained when no treatment is in effect. But in principle, a treatment effect could be a baseline for some further treatment.

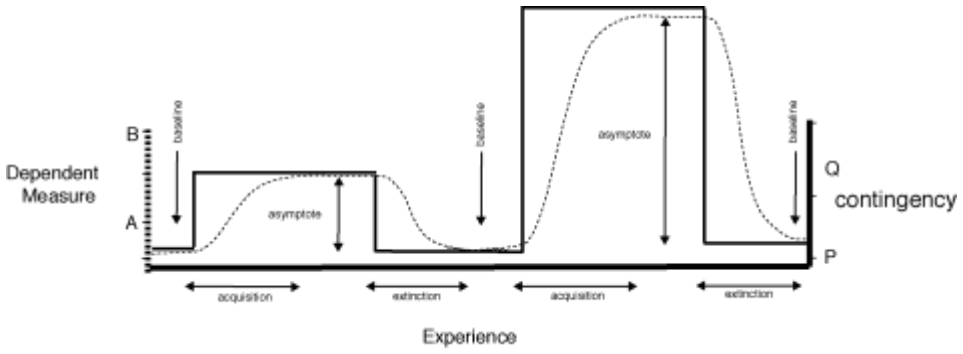



*Figure 9.25 The transition of a behavior to a new equilibrium is typically labeled acquisition or the emergence of the behavior when it changes as the result of a reinforcement contingency. It is labeled extinction or loss of the behavior when it decreases as the result of the removal of that contingency. The equilibrium, steady state, or expression of the behavior is typically labeled baseline, asymptote, or the simply the expression of the behavior.*

The use of pre-asymptotic behavior to index either baseline or treatment stimulus control is inappropriate. The functional relationship depicted in a non-asymptotic segment is arbitrary and the dependent measure would be different with any other arbitrarily chosen segment. Simply put, there are an infinite number of different points along the function from baseline to asymptote but only one asymptote.

### iii. The Emergence of Behavior Across the Entire Interreinforcer Interval

Behaviors other than the terminal behavior show reliable changes as the result of exposure to a conditioning procedure. The emergence of behavior changes across the entire interreinforcer interval are depicted in the lower left frame of Figure 9.22. Figure 9.26 depicts these changes as a separate figure. The information is the same as that presented in Figure 9.22. Roughly the latter portion of the IRI changes from flat to a positive limit while the early portion of the IRI changes from flat to a negative limit. The earliest and latest portions of the IRI become asymptotic first while the middle portions become asymptotic last.

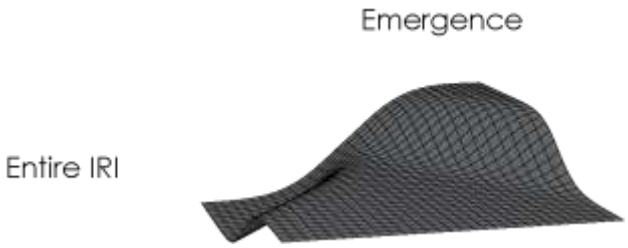



*Figure 9.26 This figure illustrates the emergence of behavior across the entire interreinforcer interval in a normalized format. It was accented in the lower left of Figure 9.22.*

### iv. Asymptotic Behavior Across the Entire Interreinforcer Interval

The lower right portion of Figure 9.22 portrays the asymptotic behavior across the entire interreinforcer interval. Figure 9.27 presents this information as a separate figure. The three-dimensional depiction could be seen as the momentary synchronous average of the behavior in each portion of the interreinforcer interval as a function of experience. Ferster and Skinner had documented with cumulative records the asymptotic behavior across the entire interreinforcer interval for a wide variety of schedules. It was after all, the moment to moment behavior of individual organisms as the result of the experienced contingencies of reinforcement and therefore an essential task of EAB. Unfortunately, cumulative records (the best analytical tools available at the time) are not sufficient to enable a straight forward understanding of the behavior. As a result, The behavior across the interreinforcement interval has generated speculation but insufficient understanding of the moment to moment behavior as a function of the imminence of reinforcement within mainstream EAB.

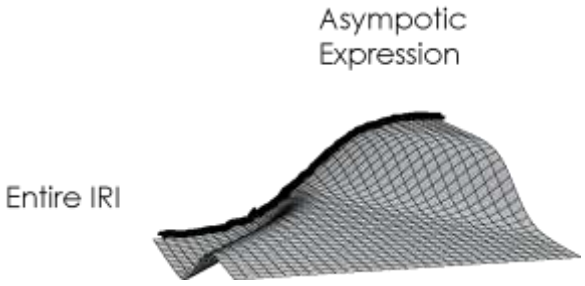



*Figure 9.27 This figure depicts the normalized asymptotic expression of behavior across the entire interreinforcer interval. It was accented in the lower right portion of Figure 9.22. This figure shows that the behavior goes "below zero" in the initial portion of the interval and goes positive in the second half of the interval.*

# CHAPTER 10

# The Determinants of Short Time Scale Organismic Adaptation: The Focus of the Experimental Analysis of Behavior

## I. Reviewing Conceptual Precursors for the Explanation of Short Time Scale Adaptation

A. The nature of explanation in EAB
   1. Evaluation of explanations, theories, and models
   2. The phenomenon we wish to understand
   3. The factors to research
   4. The domain of the explanatory task

## II. Correlation: The Cause of Short Time Scale Adaptation

A. Conceptual precursor: prevention of conceptual overload
B. Conceptual precursor: most appropriately characterizing the cause of short time scale adaptation
   1. Contiguity as a cause for short time scale adaptation
      a. Contiguity as a potential cause in the Pavlovian conditioning case
      b. Contiguity as a potential cause in the Thorndikian conditioning case
      c. Contravening evidence with respect to contiguity
   2. Correlation as a cause for short time scale adaptation
      a. Correlation as the cause in the Pavlovian conditioning case
      b. Correlation as the cause in the Thorndikian conditioning case
      c. Contravening evidence with respect to correlation
      d. Rebuttal to evidence against correlation
         i. Backward conditioning case
         ii. Continuous reinforcement case
   3. Rapprochement: "correlation versus contiguity" – an inappropriate and unnecessary dichotomy
C. Conceptual precursor: the term "contingency"
D. Overview of correlation as the cause of short time scale adaptation
E. The four elements required for short time scale adaptation
   1. Discriminably different antecedent events
   2. Functionally different subsequent outcomes
      a. Conceptual fine point: establishing operations
   3. Variance in behavior controlled by *y* reduced as a function of the value of *x*

4. Sufficient exposure to alternatives

F. Development of the specifics of the correlational/bipolar model of short time scale adaptation

1. Conceptual precursor: the cause of short time scale adaptation instantiated as a dichotomous contingency table
2. The general case of the cause of short time scale adaptation: correlation

XG. Speculations on the essential functional relationship causing short time scale adaptation

X1. Random/nonrandom subsequent functionally-significant outcome with respect to entire global context

xa. Correlated with time
xb. Correlated with behavior
xc. Correlated with explicit stimulus

X2. Random/nonrandom subsequent functionally significant outcome with respect to consecutive trials

xa. Correlated with time
xb. Correlated with behavior
xc. Correlated with explicit stimulus

X3. Random/nonrandom subsequent functionally-significant outcome with respect to portions within a trial

xa. Correlated with time
xb. Correlated with behavior
xc. Correlated with explicit stimulus

H. Conceptual follow-up: important issues that are postponed

## III. Developing a Schema to Characterize the Bipolar Correlation That Results in Short Time Scale Adaptation

A. General dimensions and terminology for the correlational space and obtained behavior

1. Subsequent outcome dimension in short time scale adaptation
2. Antecedent events dimension in short time scale adaptation
   a. Arbitrary stimuli as antecedent events
   b. Arbitrary behaviors as antecedent events
3. Linear temporal representation of the correlational space, the obtained behaviors, and the resulting stimulus control for all short time scale adaptation

B. Specific terminology for factors involved in short time scale adaptation

1. $S^*_{min}$ - $S^*_{max}$ gradient
2. $B^*_{min}$ - $B^*_{max}$ gradient
3. $B^{*'}_{min}$ - $B^{*'}_{max}$ gradient
4. $S_{min}$ - $S_{max}$ gradient
5. $t_{min}$ - $t_{max}$ gradient
6. $B_{min}$ - $B_{max}$ gradient
7. Instances of $B_{max}$

C. Outcomes of short time scale adaptation
   1. The stimulus control over the behavior gradient when antecedent correlated events are stimuli
   2. The stimulus control over the behavior gradient when antecedent correlated events are behavior
   3. The stimulus control over the behavior gradient when antecedent correlated events are time

D. Conceptual follow-up: Overview/review of the correlational space schema

## IV. Cubic Representation of the Correlational Space, the Procedures, and the Resulting Stimulus Control in Short Time Scale Adaptation

A. Limitation alert: limited graphical capability

B. Conceptual review: common procedure underlying short time scale adaptation: the instantiation of a correlation

C. Conceptual review: specific depictions for Pavlovian and Thorndikian conditioning procedures

D. Common cubic representation for Pavlovian and Thorndikian procedures and results
   1. Pavlovian and Thorndikian procedures mapped onto two orthogonally related two-dimensional surfaces
   2. Pavlovian and Thorndikian results depicted on three superimposed two-dimensional surfaces
   3. Simplistic idealized procedures and data
   4. Concrete Instantiation of a Three Dimensional Data Structure Simultaneously Representing Pavlovian and Thorndikian Procedures and Results

## V. Differences in Behavioral Output Predicted by a Bipolar Correlational and a Traditional View

A. Contrasting ramifications of traditional contiguity versus bipolar correlation predictions for short time scale adaptation
   1. Traditional contiguity-based conceptualization of short time scale adaptation
      a. Local
      b. Absolute
      c. Unipolar
   2. The correlation-based bipolar conceptualization of short time scale adaptation
      a. Global
      b. Relative
      c. Bipolar

B. Graphically representing behavior predicted by a bipolar correlation view across experience and the relative imminence of reinforcement gradient
C. A speculative homeostatic conceptualization of short time scale adaptation
D. Summary of the determinants of short time scale adaptation

## VI. The Bipolar Correlational Model of Learning and Mainstream EAB

A. Corroboration for bipolar correlational model
1. Bipolar distribution of behavior because Smin (via S*min) controls elicited escape behavior and Smax (via S*max) controls elicited approach
2. Bipolar distribution of behavior because $S_{min}$ (via $S^*_{min}$) is a negative reinforcer while $S_{max}$ (via $S^*_{max}$) is a positive reinforcer
3. Bipolar distribution of behavior because the behavior gradient is composed of elements across a behavior system
4. Bipolar distribution of behavior because the bipolar gradient is composed of interim, facultative, and terminal behaviors
5. Bipolar distribution of behavior because a lateral inhibition-like process would sharpen stimulus control across a gradient and therefore provide for the optimization of behavior

B. The normal science challenges facing the bipolar correlational model of behavior
1. The relative value of the behavior to stimuli positively and negatively correlated with the subsequent outcome
2. The momentum of the behaviors ($B^x_{min}$ and $B^x_{max}$) at the initial ($S^*_{min}$) and terminal ($S^*_{max}$) ends of the bipolar gradient
3. The form of the bipolar behavior function across the relative imminence of reinforcement gradient
4. Higher-order bipolar effect

C. Challenges to the Bipolar Correlational Model and speculative explanations for anomalous results
1. Partial reinforcement stronger than continuous reinforcement
2. Absence of strong conditioning at $S^*_{min}$
3. Absence of both strong Pavlovian and strong Thorndikian conditioning at $S^*_{max}$

# CHAPTER 10

# The Determinants of Short Time Scale Organismic Adaptation: The Focus of the Experimental Analysis of Behavior

The point of short time scale adaptation research is to understand the functional relationships between the environment and the resulting moment to moment behavior in individual organisms that emerges and is lost over the short time scale such as a learned red versus green key peck discrimination, or an FI "scallop".

Figure 10.1 illustrates that two different research procedures can be used to assess short time scale adaptation. First a reinforcement contingency is established and how behavior emerges across an organism's experience with that contingency is monitored. The details of the behavior change are of interest. The overall difference in the behavior is attributed to the difference in the contingencies between the treatment phase as compared to the antecedent and subsequent baseline phases. Alternatively, the asymptotic performance or the expression of a behavior under two different reinforcement contingencies is compared and the difference in performance in the two phases is attributed to the difference in the contingencies between the two treatment phases. In general, only the details of the asymptotic behavior are relevant for the expression measure. In either case, the dependent measure itself is the behavior of an organism to a stimulus or a reaction to a stimulus (i.e., immediate-term adaptation).

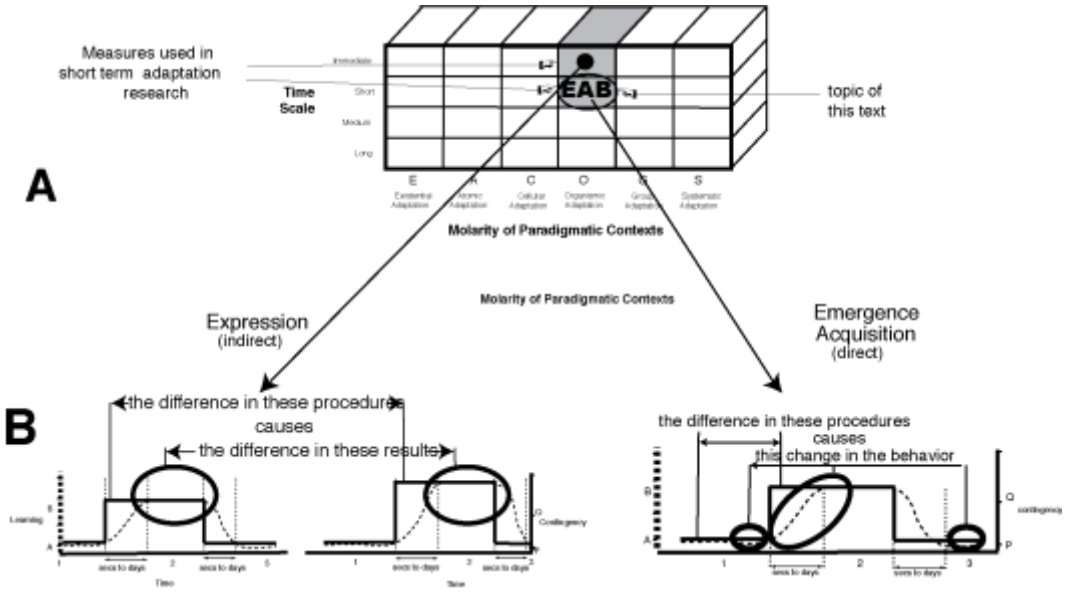


*Figure 10.1 Figure showing the measures used to study short time scale adaptation. The upper portion of the molarity by time scale structure and the lower left portion of the figure depict the expression of behavior (immediate-term adaptation). The lower left portion of the figure shows two different immediate-term adaptations as the result of two different procedures. If asymptotic functional relationships are compared following different exposures to different reinforcement contingencies, then the difference in the behaviors can be attributed to the difference in the procedures. Alternatively, the change in a functional relationship as the result of experience with a reinforcement contingency or the emergence of a functional relationship can be monitored. This is illustrated in the box labeled EAB in the time scale by level of molarity structure and the frame in the lower right.*

# I. Reviewing Conceptual Precursors For the Explanation of Short Time Scale Adaptation

If an organism is observed, systematic relationships between events or contingencies in nature and the adaptive behaviors of that organism become apparent. Our task is to understand how and why these effects happen and to develop a paradigm within which we can understand them without making up internal biological or cognitive activities, mental processes, or space aliens.

## A. The Nature of Explanation in EAB

### 1. Evaluation of Explanations, Theories, and Models

a. Unequivocally Deterministic

b. Understood Facts

c. Integration Within the Behavior Analytic and Scientific Paradigmatic Context

d. Externalistic

e. Nontautological

f. Functional Properties

g. Explicit / Unambiguous Statements and Data

h. Minimal Error

i. Principled / Testable

j. Productive

**2. The Phenomenon We Wish to Understand**

a. Moment-to-Moment Changes in Behavior

i. Across Successive Exposures to the Reinforcer (Effect of Experience, Learning, or Adaptation) (z-axis Figure 9.21)

ii. Between Each Reinforcer (Effect of Interreinforcer Interval or the Imminence of Reinforcement) (x-axis Figure 9.21)

b. In an Individual Organism's

c. Semi-permanent Adaptation

d. With Causal Factors in the Environment

e. That Emerges and is Lost Across Seconds-to-Days Time Scale

**3. The Factors to Research**

a. The correlations between behaviors and outcomes

b. The correlations between stimuli and outcomes

c. The correlations between stimuli and behaviors

d. how target situations can be seen as special cases of model situations

e. How target behaviors can be seen as special cases of model situations

f. how novel situations can be seen as special cases of model situations

g. How novel behaviors can be seen as special cases of model situations

**4. The Domain of the Explanatory Task**

a. The explanation for short time scale adaptation must cover the results of both S-S* and R-S* contingencies and must provide

the probability of a response given a stimulus.

b. The explanation for short time scale adaptation must cover both the emergence (across increasing experience with reinforcers) and asymptotic expression of that adaptation (difference in behavior as a function of the difference in schedules).

c. The explanation for short time scale adaptation must cover asymptotic behavior across the entire imminence of reinforcement gradient as well as simply terminal behavior.

d. The explanation for short time scale adaptation must cover the effect of different concurrent reinforcers for different concurrent behaviors.

# II. Correlation: The Cause of Short Time Scale Adaptation

### A. Conceptual Precursor: Prevention of Conceptual Overload

Do not attempt to read this section without carefully examining the figures as you read. The visual instantiations of the concepts taken together with the text are easier to understand than the textual statements alone.

Be very diligent about looking at each figure mentioned in each of the subsequent paragraphs and be certain that you understand ("see") the point of each reference to each figure before proceeding. Look at each portion of the figure until you can see the relationship to which the words in the text refer. It is essential that the words in the text mean something to you (see the dolphin). This will take twice as long (or more) than simply skimming over the words (learning to only say dolphin). Without studying, it is likely that important aspects of the treatment of the determinants of short time scale adaptation will be missed. Keep in mind that reading and even memorizing words without seeing the dolphin is a waste of time. If you have trouble coming to see the meaning of the text use the occasion to learn two things and benefit doubly. First, it's coming to be able to extract information from complex text and complex figures, and secondly, it's seeing the functional properties of the cause of short time scale adaptation. If a figure doesn't do "it" for you, create your own figure to illustrate the point you are working on. That is part of what it means to "study." If nothing works for you, bring up your perplexity in class. That is the primary purpose of the class.

## B. Conceptual Precursor: Most Appropriately Characterizing the Cause of Short Time Scale Adaptation

### 1. Contiguity as a Cause for Short Time Scale Adaptation

At first blush, the prerequisite of conditioning is the simple pairing (temporal touching) of the response with the reinforcer or the CS with the US. Prototypically the presence of the CS overlaps or touches the US or the CS terminates just as the US is presented thus the offset touches the onset. This class of explanation asserts that the temporal proximity of an antecedent event such as a response or a CS with a subsequent outcome such as food presentation or meat powder is the cause of learning and is therefore the learning event. For example, the learning trial would contain light "touching" response "touching" reinforcer and would result in the light producing responding; alternatively, bell "touching" meat powder would result in the bell producing salivation.

#### a. Contiguity as a Potential Cause in The Pavlovian Conditioning Case

Figure 10.2 illustrates the relevant environmental change thought to be the cause of short time scale adaptation from the contiguity perspective. In it an antecedent arbitrary stimulus (upper line labeled antecedent event) is paired with an explicit functionally important outcome (line labeled subsequent event) (CS with US). It is thought that as the result of this contiguity, the arbitrary antecedent stimulus comes to control a response related to the UR. Note the "acquired behavior" line in the right frame.

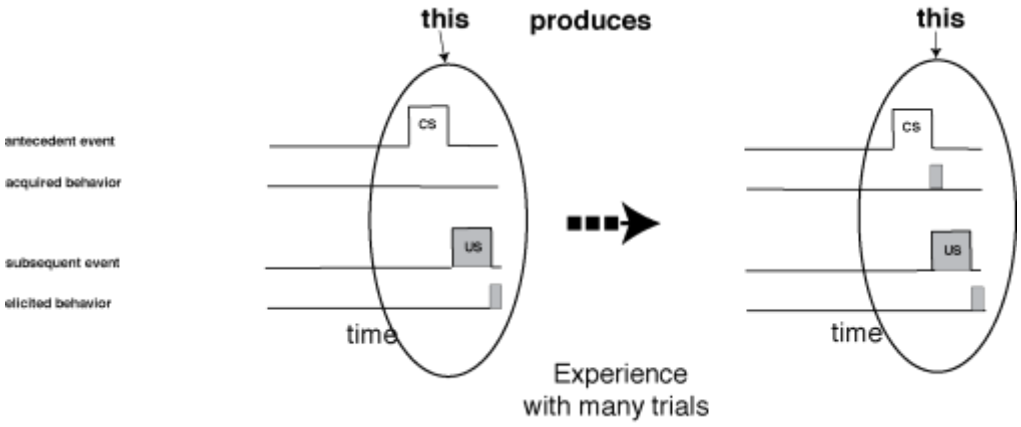



*Figure 10.2 The repetitive occurrence of the CS immediately before the US as depicted in the left frame is seen to eventually produce a behavior relate to the UR immediately after the CS as depicted in the right frame. This is essentially the same as the information presented in Figure 9.15.*

#### b. Contiguity as a Potential Cause in the Thorndikian Conditioning Case

Figure 10.3 depicts that from the contiguity perspective the contiguity of a response (arbitrary behavior), and an explicit functionally important outcome

(subsequent event) conditions the operant. Note the additional responses on the arbitrary behavior line in the right frame.

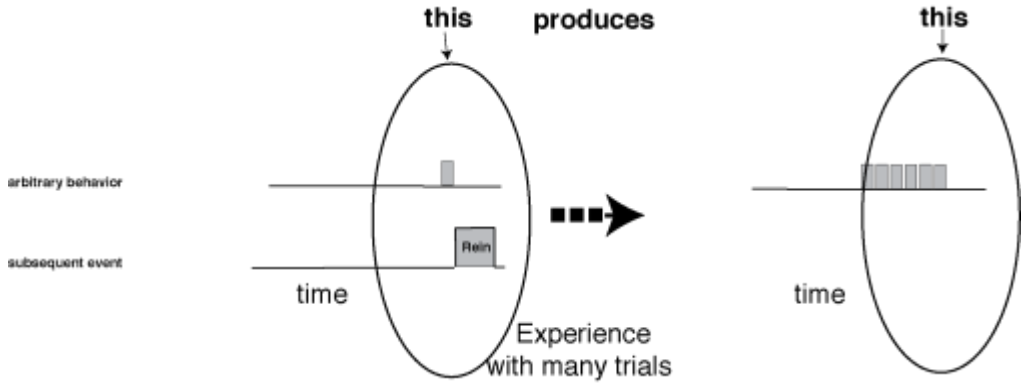



*Figure 10.3 The repetitive occurrence of the reinforcer immediately after a response as is depicted in the left frame is seen to eventually produce occurrences of the response as is depicted in the right frame. This is essentially the same as the information presented in Figure 9.18.*

### c. Contravening Evidence with Respect to Contiguity

Food presentation which occurs with an equal frequency when pecks occur and when pecks don't occur; or if meat powder is presented with an equal frequency with respect to both the trial stimulus and the intertrial stimulus, then conditioning does not occur.

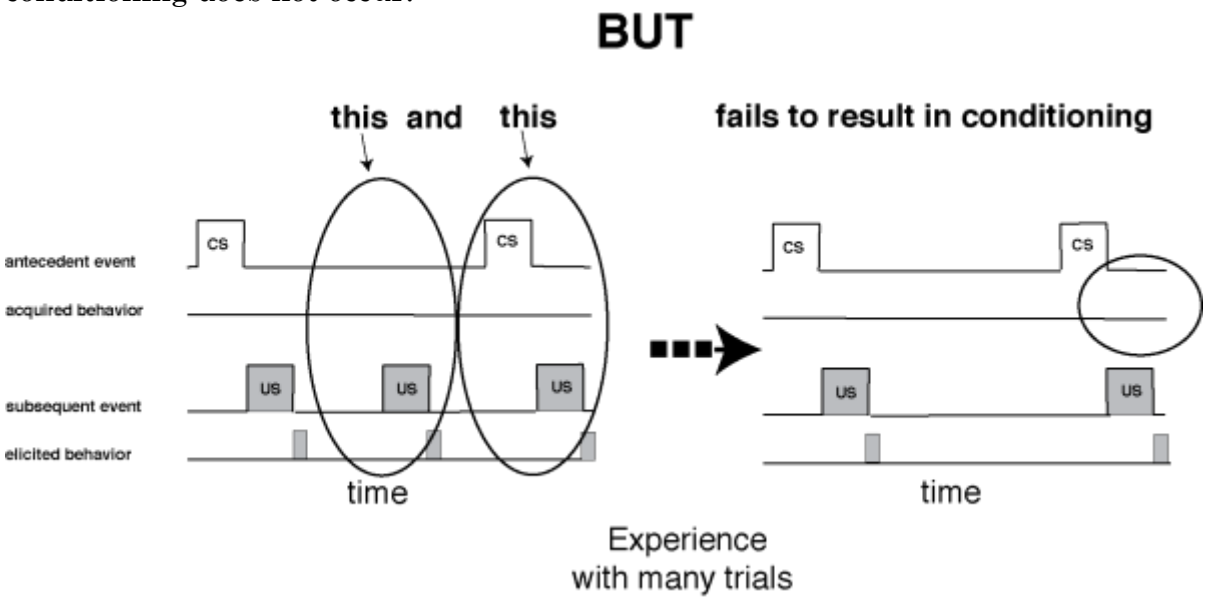



*Figure 10.4 If the conditions which produced conditioning in Figure 10.2 are exactly replicated with respect to the contiguity of the CS and US (the procedure within the right circle in the left frame of the figure), but <u>also</u> include a US in a random position in the intertrial interval (the procedure in the left circle in the left frame of the figure) as is illustrated in the left frame of this figure, then conditioning does not occur, as is depicted in the right frame.*

For example, [bell "touching" meat powder & no bell + meat powder], results in bell producing no salivation even though bell and meat powder in this second example were exactly as contiguous as in the first example (Compare Figure 10.2 with the right portion of the left frame in Figure 10.4); Alternatively, [light "touching" peck "touching" reinforcer & light + no peck + reinforcer], results in light producing no peck even though the peck and reinforcer were also exactly as contiguous in this procedure as in the first example given in Figure 10.2.

It would appear that the learning task or conditioning trial must be seen from a broader perspective which contains both the pairing of behavior or a stimulus and the reinforcer and what is occurring at other times.

### 2. Correlation as a Cause for Short Time Scale Adaptation

With further thought, a somewhat more complex conceptualization appears to be the prerequisite for short time scale adaptation. If there is a positive correlation between the occurrence and the temporal position of the response and the reinforcer or the bell and meat powder, then conditioning will occur. For example, [no bell + no meat powder & bell + meat powder], results in no bell producing no salivation and bell producing salivation. Alternatively, [no light + no peck + no reinforcer & light + peck + reinforcer], results in no light producing no pecking and light producing responding. It is important to note that the correlation refers to either or to both the occurrence / non-occurrence of the event "bell" and the event "meat powder", or the positioning of the two events in time. In this latter sense, a maximally correlated pair of events is also maximally contiguous and vice versa.

#### a. Correlation as the Cause in the Pavlovian Conditioning Case

Figure 10.5 illustrates that the relevant environmental events from a correlation perspective are the correlation of an explicit antecedent arbitrary stimulus and an explicit functionally important outcome [no CS with no US as well as CS with US]. As the result of this correlation, the arbitrary antecedent stimulus comes to control a response related to the UR.

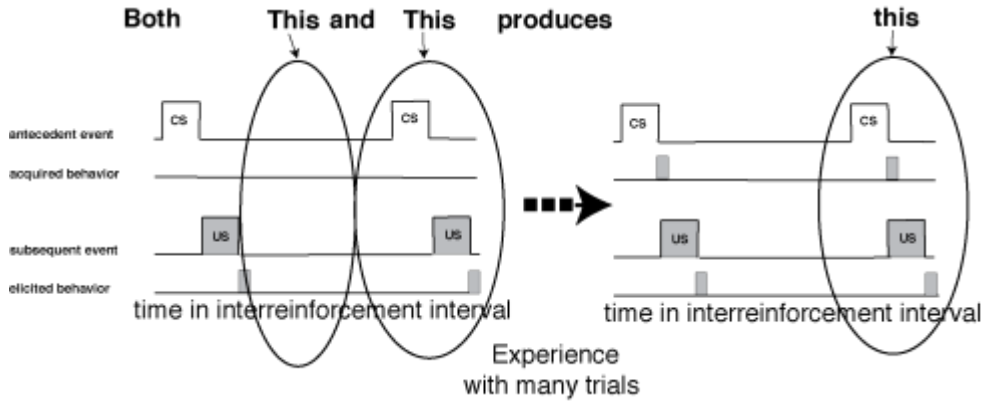


*Figure 10.5 The repetitive occurrence of the CS immediately before the US (right circle of left frame) and the nonoccurrence of the CS (left circle of left frame) when there is no US as is depicted in the left frame is seen to eventually produce the occurrence of a behavior related to the UR immediately after the CS as is depicted in the right frame.*

### b. Correlation as the Cause in the Thorndikian Conditioning Case

Figure 10.6 depicts that from a correlation perspective the correlation of a response, and an explicit functionally important outcome, is responsible for conditioning an arbitrary behavior.

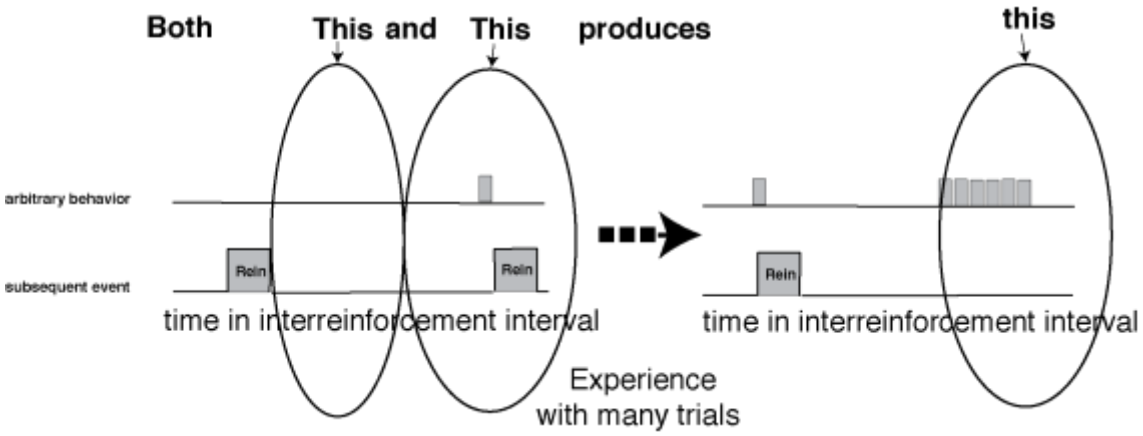



*Figure 10.6 The repetitive occurrence of the reinforcer immediately after the response (right circle of left frame) and the non-occurrences of the reinforcer (left circle of left frame) in the absence of the response as is depicted in the left frame is seen to eventually produce occurrences of the response as is depicted in the right frame.*

### c. Contravening Evidence with Respect to Correlation

Backward conditioning seems substantially weaker than forward conditioning even though the elements are equally correlated. This anomaly is thought to undercut the viability of simple correlation as a cause of conditioning.

A second criticism of correlation accounts is based on the lack of correlation between a trial and the reinforcer when every trial is followed with the reinforcer because there is no absence of the reinforcer.

### d. Rebuttal to Evidence Against Correlation

#### i. Backward Conditioning Case

- *Deny the force of the argument*. Backward contiguity also results in poor conditioning so if poor backward conditioning undercuts the plausibility of correlation as a cause, then poor backward conditioning equally undercuts the plausibility of contiguity as a cause of conditioning. It is ungracious to a fault for proponents of contiguity to invoke the failures

of backward conditioning to dismiss correlation as a cause of conditioning.

- *Deny contradiction*. It is not necessary for forward and backward conditioning to be equivalent for the notion of correlation (or contiguity) to be important. It's relatively simple to specify that the response or CS must precede the reinforcer. (It is unnecessary, but a plausible albeit ad hoc causal machinery for this asymmetry could be advanced by claiming that it is plausible that forward correlations and forward contingencies would have more of a positive impact on reproductive success.)
- *Deny the appropriateness of the results*. Results failing to show backward conditioning may be measuring the wrong behavior. The behavior conditioned at the beginning of the interfood interval (the procedural instantiation of backward conditioning) may be different than the behavior at the end of the interfood interval.
- *Deny the appropriateness of the procedure* (e.g., claim that the backward conditioning procedures which result in less food approach responding were not appropriate procedures for testing the impact of correlation on short time scale adaptation.

#### ii. Continuous Reinforcement Case

- Both the within trial temporal correlation of stimuli and outcomes (i.e., a period of time with no reinforcer followed by a period of time with a reinforcer) as well as the trial-to-trial correlation of trial-to-outcome must be considered, so there is no necessity for non-reinforced trials in order to instantiate a correlation.

### 3. Rapprochement: "Correlation Versus Contiguity" – An Inappropriate and Unnecessary Dichotomy

The correlation versus contiguity controversy is more apparent than real, in that in a typical conditioning paradigm, contiguity is instantiated by creating a strong within trial correlation. Stimuli that are not contiguous are also uncorrelated with the subsequent reinforcer. For example, a stimulus which occurs at the beginning of the interfood interval is negatively correlated with the the food presentation which is at the end of the interval in terms of its temporal nearness with the reinforcer. Note that a conceptualization of contiguity (as opposed to correlation) that additionally requires the absence of the antecedent event to go with the absence of the subsequent outcome simply redefines contiguity as correlation.

Correlation would seem to be the more general term in that it refers to both a within trial correlation based on the relative imminence of reinforcement as well as a trial-to-trial correlation (such as trials with and without reinforcement).

It is important to be aware of the issues underlying the discussion, but it is equally important to see the "controversy" as a temporary stage in the evolution

of an adequate description of the factors determining short time scale adaptation. The present usage of correlation is with respect to within a trial, as well as, between trials.

Skinner's emphasis on contiguity was only a reaction to, two then currently held views about the nature of reinforcement. One was the position asserting that a response dependency was necessary. The other was that some internal homunculus would be necessary to use the information (i.e., the correlation) to know what to do. Skinner's point with respect to the first was that there was no mechanism whereby the difference between contiguity and dependency could be determined by the animal. Therefore, contiguity was the least objectionable characterization. Skinner's point with respect to the second was that the only real data available to the researcher were the environmental relationships. Anything else such as "the use of information" could not be validly separated from a claim that the space aliens did it. Therefore, to Skinner contiguity was again the least objectionable characterization.

With respect to Skinner's choice of a contiguity conceptualization, note that the correlation view is also neutral with respect to whether the consequence is dependent on the response. In principle, there could be only a statistical relationship between the response and the consequence in a correlational view. Correlation is as Humeian as contiguity. As to Skinner's second point, a correlational view is in point of fact just as externalistically descriptive as a contiguity view and requires no mind that uses information. There is a correlation between storm clouds and rain (i.e., information) but that certainly does not require a storm god to react to the information.

### C. Conceptual Precursor: The Term "Contingency"

The term contingency is used in the literature to refer to the occurrence of food presentation or other subsequent event after a peck or some other behavior. Unfortunately, there is some ambiguity in its precise meaning. Even though the different definitions could be the same under some conditions, they may be different in others. Some researchers use the term to designate that food is dependent on a peck; for others, the term indicates that the food is simply contiguous with the peck; while still others mean that there is a correlation between the peck and the food presentation.

Other undesirable baggage of the term contingency is that historically the term has not been used with respect to Pavlovian conditioning and as a result it makes discussing commonalities between Pavlovian and Thorndikian conditioning cumbersome. Finally, the dictionary defines contingency as when something happens purely by chance i.e., it is randomly related to the prior events and shows no specific correlation whatsoever and any contiguity is purely coincidental.

In the present text, contingency will be synonymous with correlation and does not imply (or preclude) a dependency nor does it imply that internal intermediaries are relevant in any way; additionally, the term is equally applicable to Pavlovian and Thorndikian conditioning. It should go without

stating at this point that contingency is strictly externalistic and any internal state related to it is irrelevant.

### D. Overview of Correlation as the Cause of Short Time Scale Adaptation

A simple version of the causal (and explanatory) correlation underlying short time scale adaptation is illustrated in Figure 10.7.

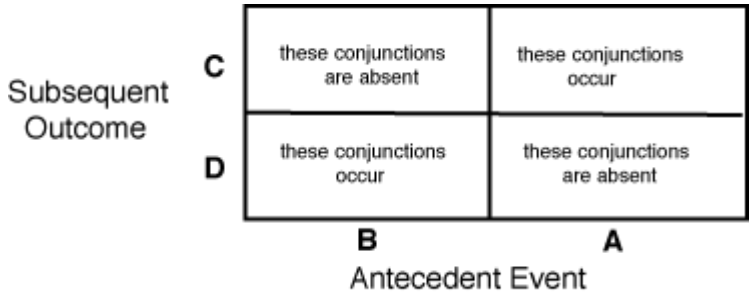



*Figure 10.7 The conjunctions necessary for short time scale adaptation set into a 2x2 contingency table with antecedent events on the x-axis and subsequent outcomes on the y-axis.*

Simply put, short time scale behavioral adaptation implies 1) two or more antecedent events (A and B), Amber and Blue light or Approach such as a key peck and a behavioral Blank such as doing nothing or no key peck; 2) two or more subsequent outcomes (C and D), Candy and Dross for example; 3) a reliable relationship between the elements [(A with C, and B with D), and no, or at least fewer, conjunctions of A with D and B with C]; and 4) exposure to more than one conjunction (both A/C and B/D); and sufficient A/C and B/D exposures to make A/D and B/C conjunctions "clearly" missing.

These are the four elements of a correlation and the four elements necessary for short time scale organismic adaptation. This conceptualization is applicable for both S-S* correlations (Pavlovian conditioning) illustrated in the right frame of Figure 10.8 and for R-S* correlations (Thorndikian conditioning) illustrated in the left frame of Figure 10.8.

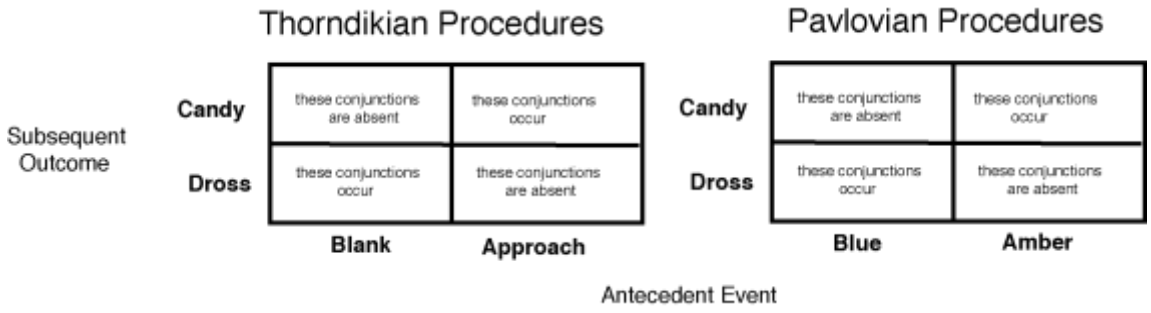



*Figure 10.8 The conjunctions necessary for Thorndikian and Pavlovian conditioning set into individual two 2x2 contingency tables.*

### E. The Four Elements Required for Short Time Scale Adaptation

Recall yet again that the behavior analytic answer to "what caused the animal to respond?" is the specification of the procedure not an appeal to some internal state. In this case it is the causal instantiation of Nevin's descriptive law "In order for there to be a difference in behavior, there must be two different stimulus conditions with two different schedules of reinforcement." the causal statement being, if there is a difference in stimulus conditions associated with a difference in probabilities of functionally significant outcomes (reinforcement) then there will be a difference in behaviors.

#### 1. Discriminably Different Antecedent Events

Antecedent events include bell and no bell or amber and blue in the Pavlovian conditioning case, or key peck and no key peck or approach and blank in the Thorndikian conditioning case. In point of fact, even a continuous series of tones ranging from high to low tones or from unreinforced high tones through the reinforced tones and on to unreinforced lower tones, or a continuous gradient of behaviors, or even simply the passage of time are equally applicable as antecedent events. The difference in the antecedents must be capable of being discriminated (i.e., $\geq$ 1 jnd). Presumably, the more similar and less distinct the antecedent stimuli, the longer it will take the correlation to come to control differentiated behavior (e.g., the "$\alpha$" in the Rescorla & Wagner model).

#### 2. Functionally Different Subsequent Outcomes

Subsequent outcomes include meat powder and no meat powder, or food access and no food access or as given in Figure 10.8 candy and dross. Even a continuous gradient of warmth ranging from warm to cold, or from too hot through ideal to too cold for that matter are equally appropriate. The difference in the outcomes must be capable of being discriminated (i.e., $\geq$1 jnd). The stimuli in this dimension must be functionally significant. One mechanism for this effect would be that they must be different enough to cause a behavioral adjustment (Donahoe & Palmer). While a behavioral adjustment is irrelevant to a radical behavioral approach it provides a convenient explanatory scaffolding  Presumably, the more similar and less distinct the subsequent outcomes, the longer it will take a correlation to come to control differentiated behavior (e.g., the "ß" in the Rescorla & Wagner model).

##### a. Conceptual Fine Point: Establishing Operations

Some subsequent outcomes require motivating or establishing operations to enable them to be functionally significant. For example, in the case of food - no food outcomes, a prerequisite is food deprivation. Otherwise the food / no food outcomes may not be different, e.g., would not control a behavioral adjustment. Operations that establish the difference between stimuli (such as the operation of food deprivation), are labeled motivating or establishing operations. Food

deprivation establishes the difference between a meal and nothing. For example, after food deprivation a meal will control a behavioral adjustment, after satiation a meal will not control a behavioral adjustment.

### 3. Variance in Behavior Controlled by *y* reduced as a Function of the Value of *x*

In the functional Pavlovian conditioning case, there must be less variance in the subsequent outcome given the antecedent event than without the antecedent event. As the most extreme example, [(bell with meat powder) (no bell with no meat powder) and no (bell without meat powder) and no (no bell with meat powder)]. Alternatively, in the functional Thorndikian conditioning case, there must be less variance in the subsequent outcome given the antecedent behavior than without the antecedent behavior. As the most extreme example [(key peck with food) (no key peck with no food) and no (key peck with no food) and no (no key peck with food).]

In the ideal procedure, every aspect of the meat powder and food presentation are perfectly predicted in both the event and temporal sense by the bell and key peck respectively. However, a perfect correlation is not necessary. However, the greater the correlation, then presumably, the faster and stronger the conditioning. It could be argued that the reduced variance in the values of *y* as a function of *x* as compared to the variance in y as a function of the mean of y causes or enables a reduction or greater efficiency in the behavioral adjustment to the subsequent outcome.

Note that the seemingly contradictory and anomalous partial reinforcement effect (key pecking when only occasional key pecks are reinforced is typically stronger than when every key peck is reinforced) is ignored for the moment and will be covered in a later section.

### 4. Sufficient Exposure to Alternatives

The animal must have sufficient exposure to the two different positive conjunctions and the absence of the two negative conjunctions, i.e., [(AC) and (BD) and not (AD) and not (BC)]. It is presumed that the greater the range of exposures, the faster and stronger the conditioning. It should be noted that only a few conjunctions of [(A with C) and (B with D) and not (A with D) and not (B with C)] may not be a sufficient exposure to result in learning. Alternatively, a few of the negative conjunctions may not be sufficient to entirely undercut learning. It is also important to note at this point that the exposure to the positive subsequent outcome and its correlated stimuli is not necessarily the same as the exposure to the negative signal and the negative subsequent outcome. This issue will be covered in more detail below.

Many questions remain concerning effective and ineffective correlations and the staged exposure to those correlations. The final and complete resolution of these questions is shamelessly left for future "normal science".

## F. Development of the Specifics of the Correlational/Bipolar Model of Short Time Scale Adaptation

### 1. Conceptual Precursor: The Cause of Short Time Scale Adaptation Instantiated as a Dichotomous Contingency Table

The dichotomous case is the simplest conceptualization of a correlation. In it there are two antecedent events A and B (for example Amber and Blue lights) that have a perfectly reliable relationship with two subsequent outcomes C and D (for example, Candy and Dross) and the organism is given exposure to the occurrence of the [AC and BD outcome and the non occurrence of the AD and BC outcome]. Alternatively, the antecedent events could be Approach such as pecking a key or a behavioral Blank such as simply standing there with the outcome being Candy or Dross.

Figure 10.9 recalls the outcome conjunctions.

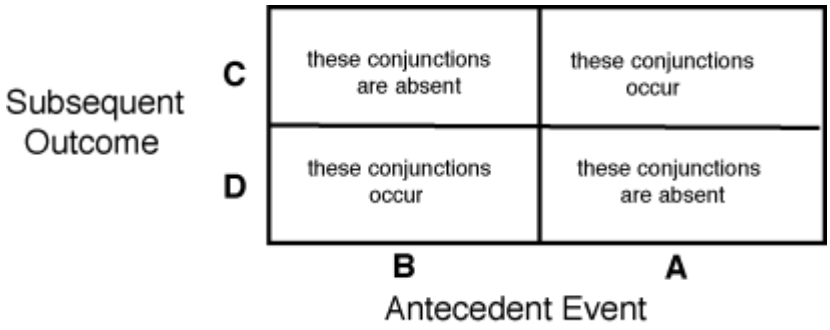



*Figure 10.9 A re-presentation of Figure 10.7. The conjunctions necessary for short time scale adaptation set into a 2x2 contingency table.*

### 2. The General Case of the Cause of Short Time Scale Adaptation: Correlation

The scatter plot given below in Figure 10.10 is intended to depict a continuous set of antecedent events and a continuous set of subsequent outcomes that are correlated. Figure 10.10 could be seen as the continuous version of the simplistic relationship illustrated in Figure 10.7 and again in Figure 10.9. The fundamental issue remains; it is only necessary for the variability in predicting *y* based on *y*' (best estimate based on a correlated x) to be functionally better than predicting *y* based on the mean y. This can be seen by comparing the variance in the subsequent outcome around the mean, depicted to the left of the y-axis to the variance around the predictor *y*' as is represented in the lower left of the figure.

If you examine Figure 10.10 and imagine drawing a line from each dot back to the horizontal line that bisects the scatter plot with half the dots above and half the dots below, those line lengths are depicted as a distribution to the left of the y-axis. You could imagine the data could represent how far you would have to travel carrying apples located on the trees as positioned in an orchard where the dots are located. If you build an access road along the diagonal rather than

horizontally across the orchard at the mean, then the distance you would have to carry apples would be represented with the distribution in the lower left of the figure. As can be seen, the total deviations are less than from the mean.

In typical conditioning procedures, the distributions of antecedent events and subsequent outcomes are strongly bimodal, and approach a cluster of dots in the lower left and upper right quadrants.

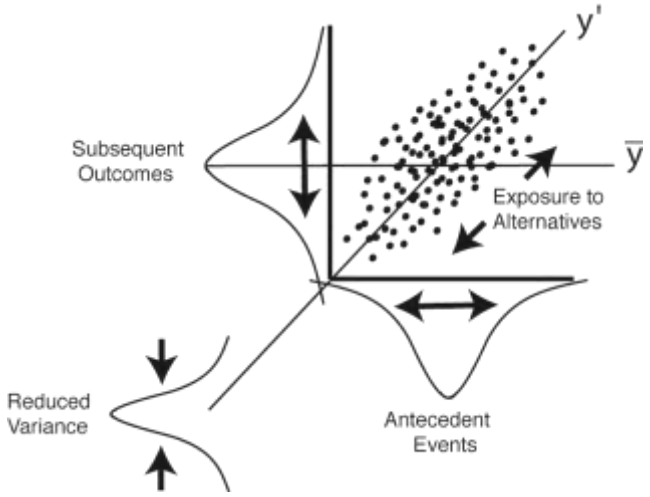


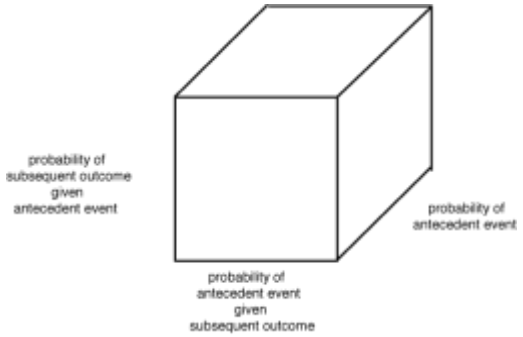

*Figure 10.10 The conjunctions of antecedent events correlated with subsequent outcomes and the conditions necessary for short time scale adaptation provided as an idealized scatter plot in the continuous case. The distribution below the x-axis is the distribution of antecedent events. The distribution to the left of the y-axis is the distribution of subsequent outcomes. The distribution in the lower left of the figure is the distribution of the conjunctions of events around the regression function. Note that the variance around y' is less than the variance around $\bar{y}$.*

## XG. Speculations on the Essential Functional Relationship Causing Short Time Scale Adaptation

Virtually all explanations for short time scale adaptation involve a relationship between antecedent events and subsequent outcomes. In fact, most typically, unless there is some correlation between elements, the behavior change is not considered "learning." In that latter case the behavior change is said to be non-associative and is therefore excluded from treatment.

How adaptation changes as a function of changes in that relationship is the dependent measure and is of fundamental importance for all models of learning. Figure 10.11 depicts the various classes of relationships between arbitrary antecedent events and functionally important subsequent outcomes as three orthogonal axes.

There are two dimensions across which the antecedent and subsequent events can be related.




*X Figure 10.11*

**X1. Random/Nonrandom Subsequent Functionally-Significant Outcome With Respect to The Entire Global Context**

**xa. Correlated With Time**

**xb. Correlated With Behavior**

**xc. Correlated With Explicit Stimulus**

**X2. Random/Nonrandom Subsequent Functionally Significant Outcome With Respect to Consecutive Trials (z axis in figure 9.21)**

**xa. Correlated with Time**

**xb. Correlated with Behavior**

**xc. Correlated with Explicit Stimulus**

**X3. Random/Nonrandom Subsequent Functionally-Significant Outcome with Respect to Portions Within a Trial(x axis in figure 9.21)**

**xa. Correlated With Time**

**xb. Correlated With Behavior**

**xc. Correlated With Explicit Stimulus**

### H. Conceptual Follow-Up: Important Issues that are Postponed

The treatment of interaction effects are held in abeyance until after the main effects are presented. these include the partial reinforcement effect, and the absence of a strong simple relationship between Pavlovian conditioning and Thorndikian conditioning,

# III. Developing a Schema to Characterize the Bipolar Correlation that Results in Short Time Scale Adaptation

The present view of short time scale adaption is somewhere between a simple obvious derivative of Hearst and Jenkins (1974) and only being consistent with their perspective. It is not asserted that they would have agreed with all aspects of the present view.

Productively comprehending the relationships discussed in this chapter is extremely difficult the first time through, unless you have a visual representation of the information. Look at the image of each gradient in Figure 10.12 as it is mentioned in the text, and look back and forth between gradients when a relationship or comparison is made between the two

### A. General Dimensions and Terminology for the Correlational Space and Obtained Behavior

General terminological conventions and a spatial representation for the bipolar correlation model for learning will be established and overviewed in this section (Section A) to provide labels and a graphic that simplifies conceptualizing the correlational space, and its behavioral results. The finer details pertaining to those terms will be presented and elaborated in the following section (Section B). This material is new and complex. It is best understood by first reading the overview in section A, then the details in section B, then reading the entire thing over again.

At its simplest, an organism could be exposed to irrelevant events such as a pin dropping or significant events such as a bucket of food. In order for presignificant event behaviors to be acquired the significant event would have to be regularly preceded by some event. For example, free access to food could occur when a green light came on but not when it was red, free access to food could occur following a response but not otherwise, or free access to food could occur for 1 minute at the end of each hour but not otherwise.

Because time is ubiquitous and an inevitable component of all other contexts. It is the atom or common denominator of all contexts and will be used as the fundamental analytical context for the present analysis. It is important to note that any other differentiating procedure such as a color change is necessarily

added to or layered on top of the temporal structure, in that time is an inevitable part of any other stimulus class.

### 1. Subsequent Outcome Dimension in Short Time Scale Adaptation

The bipolar correlation framework illustrated in Figure 10.12 is created from the separation of functionally significant outcomes or reinforcers in time and is depicted as a heavy solid line in Figure 10.12. The subsequent outcome dimension is labeled the $S^*_{min}$ - $S^*_{max}$ continuum or the $S^*_{min}$ - $S^*_{max}$ gradient. It is the graphical instantiation of: the upper arrow in figure 9.6; the *x*-axis in the lower left portion of Figures 9.15, 9.18, and 10.3; The x-axis in the lower portion of figures 10.2, 10.4, 10.5,and 10.6; and the vertical axis in the contingency tables in Figures 10.7, 10.8, 10.9 and 10.10.

The $_{min}$ and $_{max}$ indicate that the outcome (such as a bucket of food) varies from the least to the most. This variation can be dichotomous as no food versus food or no shock versus shock; or a continuous vector of values as $C_1$ to $C_{99}$ where there are 99 amounts of food each larger than the one before. The superscript asterisk designates that the stimulus is functionally significant, and is typically biologically significant as well, such as food presentation or shock. This gradient defines the dimension within which all other elements of the bipolar correlation framework are created and are structured. the $S^*_{min}$ - $S^*_{max}$ gradient defines the causal space. If a behavioral adjustment mechanism is used, then this gradient is the environmental events which create the behavior adjustment gradient. If a homeostatic motivational tension with tension-reducing reinforcement mechanism is used, then $S^*_{max}$ is the tension reducing homeostatic event. Most typically $S^*_{max}$ is a biologically significant event but it could also be an arbitrary conditioned or higher-order reinforcer. $S^*_{max}$ is the dominant event regardless of whether it is appetitive (e.g., food) or aversive (e.g., shock).

Typical Pavlovian conditioning or Thorndikian conditioning procedures are straightforward to conceptualize within this framework. Food (or shock) presentation at the end of the learning trial in each procedure is $S^*_{max}$. Complex cases could be envisioned but their classification would be an empirical question. For example, the repeating series: shock, red, green, blue, food ... shock red green blue food ... which cycles continuously without a break could function as shock = $S^*_{min}$, food= $S^*_{max}$; or alternatively as red = $S^*_{min}$, and shock = $S^*_{max}$. Presumably, the relative strengths of the behaviors controlled by the food and shock would determine which is best characterized as $S^*_{max}$.

In review, a linear representation of the $S^*_{min}$ - $S^*_{max}$ gradient across the temporal dimension is depicted in Figure 10.12 as a heavy line, with the differentiating temporal dimension directly below it designated with a dotted line.

### 2. Antecedent Events Dimension in Short Time Scale Adaptation

These are the incidental events that are correlated with the subsequent outcome dimension and are conditioned by their relationship with the subsequent outcome gradient. The antecedent events dimensions are labeled the $S_{min}$ - $S_{max;}$

$B_{min}$ - $B_{max;}$ and the $t_{min}$ - $t_{max}$ gradients. They are the graphical instantiations of: the lower two arrows in figure 9.6; the x-axis in the upper left portion of Figures 9.15, 9.18, 10.3 and 10.6; The x-axis in the lower portion of figures 10.2, 10.4, 10.5,and 10.6; and the vertical axis in the contingency tables in Figures 10.7, 10.8, 10.9 and 10.10

#### a. Arbitrary Stimuli as Antecedent Events

When the incidental event dimension is made up of arbitrary stimuli which become conditioned by their correlation with the outcome it is labeled the $S_{min}$ - $S_{max}$ continuum or gradient. Often the $_{min}$ and $_{max}$ simply indicate the two ends of a stimulus continuum established by its positive or negative temporal or probabilistic correlation with the subsequent outcome. The absence of an asterisk superscript indicates that the stimuli are arbitrary. This dimension is indicated on the horizontal axis of Figure 10.9 or either of the figures in figure 10.8 . A linear representation of the $S_{min}$ - $S_{max}$ gradient is depicted in Figure 10.12 as the third line from the bottom.

#### b. Arbitrary Behaviors as Antecedent Events

When the incidental event dimension is made up of arbitrary behaviors which become conditioned by their correlation with the outcome it is labeled the $B_{min}$ - $B_{max}$ continuum or gradient such as that illustrated in left frame of Figure 10.8 and which could be on the *x*-axis of Figure 10.9 it is labeled the $B_{min}$ - $B_{max}$ continuum or gradient due to its positive and negative correlation with the subsequent outcome. The absence of an asterisk superscript indicates that the behaviors are arbitrary. A linear representation of the $B_{min}$ - $B_{max}$ gradient is depicted in the first and second line from the bottom in Figure 10.12 below. Note that most typically the dependent variable in operant conditioning considers only $B_{max}$ occurrences. (the bottom line) as will be discussed below.

### 3. Linear Temporal Representation of the Correlational Space, the Obtained Behaviors, and the Resulting Stimulus Control for All Short Time Scale Adaptation

The schematic below (Figure 10.12) provides a linear depiction of the relationship between the arbitrary stimulus and arbitrary behavior gradients overviewed in the previous sections. Their presentation in Figure 10.12 shows the case where the elements along each of the gradients are discriminable, and where there is a bipolar correlation between the antecedent events and subsequent outcomes. For instance, the elements on the right edge of the figure are all maximally positively correlated with $S^*_{max}$ while the elements on the left edge of the figure are all maximally negatively correlated with the subsequent $S^*_{max}$. Said from the opposite perspective; stimuli, behaviors, and time are positioned on the figure as a function of their correlations with the $S^*_{min}$ - $S^*_{max}$ gradient. For example, the arbitrary stimulus most correlated with $S^*_{max}$ is positioned in the rightmost

portion of the figure. As a second example, the temporal stimulus furthest removed from $S^*_{max}$ is positioned in the leftmost portion of the figure.

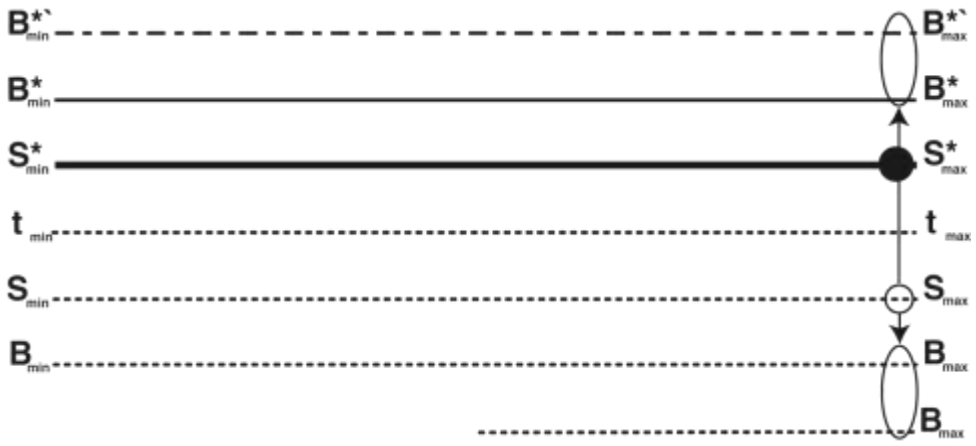



*Figure 10.12 A linear representation of the gradients pertaining to short time scale adaptation such that the various gradients involved are correlated (i.e., the elements portrayed along each gradient are the ones that always occurs in the same position with respect to the elements along the the* $S^*_{min}$ - $S^*_{max}$ *gradient). The heavy line depicts the* $S^*_{min}$ - $S^*_{max}$ *gradient; the other resulting gradients are as described in the text.*

### B. Specific Terminology for Factors Involved in Short Time Scale Adaptation

In the natural world, significant events occur. They could be food, water, shock, or any of a number of biologically significant events labeled primary reinforcer or unconditioned stimuli, or stimuli that elicit a behavioral adjustment (Donahoe & Palmer).

Three caveats are: 1) the effectiveness of the significant event is often dependent on motivational operations that establish or abolish its effectiveness, 2) arbitrary stimuli can come to function as if they were biologically significant (e.g., conditioned reinforcers) which leads to the general term "functionally significant", and 3) the significant event could be a final worst event rather than a final best event. This third case would occur in a situation where the final event was shock.

The present paradigm labels these significant stimuli as $S^*_{max}$. It is the most important event in the local context. It is the stimulus intrinsically associated with the "best" (or worst) event in a situation (i.e., food and shock presentations are seen as stimuli). The context in which $S^*_{max}$ occurs, may or may not have events in addition to time positively or negatively correlated with it.

#### 1. $S^*_{min}$ - $S^*_{max}$ Gradient

In the typical research setting, repeated occurrences of $S^*_{max}$ presentations (e.g., food presentations) are deliberately preceded by other stimuli such as a CS (e.g., bell then meat powder) and/or behaviors such as a peck (e.g., peck then food); in relatively short trials

In traditional repeated exposures to the same reinforcement contingency in which $S^*_{max}$ (or the best conditions) occurs, it ipso facto also establishes the worst conditions in the situation with its intrinsically associated stimulus, $S^*_{min}$. In sum, there are stimulus conditions when $S^*_{max}$ is most likely and stimulus conditions when $S^*_{max}$ is least likely. In any situation with a regularly occurring $S^*_{max}$ there is a point where the $S^*_{max}$ is most imminent or probable and also necessarily, a point where it is least imminent or least probable. As a result, there is a gradient or continuum established between those two end points labeled the $S^*_{min}$ - $S^*_{max}$ continuum or gradient. Because it is functionally significant, it is this gradient that establishes the other gradients. It is, therefore, illustrated with a thick line in Figure 10.12.

### 2. $B^*_{min}$ - $B^*_{max}$ Gradient

A gradient of behaviors, the $B^*_{min}$ - $B^*_{max}$ continuum, is elicited by the $S^*_{min}$ - $S^*_{max}$ gradient (it is a continuous version of a UR). The expression of these behaviors is a function of the $S^*_{min}$ - $S^*_{max}$ gradient. The origin of this series of innate or fixed behaviors is via long-term adaptation. These are the reflex responses or modal action patterns associated with each portion of the $S^*_{min}$ - $S^*_{max}$ gradient through evolution (such as salivation to meat powder and leaving a situation where no food is available). This gradient is identified by Timberlake as the various stages of prey attainment. This gradient is illustrated in Figure 10.12 as a line, $B^*_{max}$ is the behavior adjustment elicited or controlled by $S^*_{max}$, while $B^*_{min}$ is the behavior adjustment elicited or controlled by $S^*_{min}$.

Note that when this behavior (or its compensatory reaction see below) can be seen as being "directed," the $S^*_{min}$ - $S^*_{max}$ gradient controls its vector as the result of long-term adaptation. The $S_{min}$ - $S_{max}$ gradient (see below) can control the vector of that direction as the result of short time scale adaptation. The prototypical example of the ontogenic control of this class of directed behavior is sign-tracking in pigeons.

### 3. $B^{*'}_{min}$ - $B^{*'}_{max}$ Gradient

There is also a $B^{*'}_{min}$ - $B^{*'}_{max}$ gradient which is generally seen as the compensatory behaviors for the behaviors along the $B^*_{min}$ - $B^*_{max}$ gradient. The time course across which these compensatory behaviors emerged is not necessarily always long-term adaptation. For the present, as a simplifying assumption, the origin of the reaction is considered to have occurred via long-term adaptation and the behaviors are seen as compensatory reflexes elicited by the $B^*_{min}$ - $B^*_{max}$ gradient. The uncertainty as to whether this gradient is phylogenic or ontogenic, is indicated by the dot-dashed line in Figure 10.12.

### 4. $S_{min}$ - $S_{max}$ Gradient

Many stimuli and behaviors are occurring at all times; most occur randomly with respect to the various portions of the $S^*_{min}$ - $S^*_{max}$ gradient because they are

occurring for reasons totally independent of the $S^*_{min}$ - $S^*_{max}$ gradient. However, some stimuli may be correlated (for whatever reason) with some particular portion of the $S^*_{min}$ - $S^*_{max}$ gradient. It is these correlated stimuli that become the $S_{min}$ - $S_{max}$ gradient. The elements of the $S_{min}$ - $S_{max}$ gradient are "extracted" or "selected" from the context of a wide variety of randomly occurring arbitrary explicit stimuli much as a signal averager extracts any consistent signal from the random background noise. This gradient is illustrated with a dotted line in Figure 10.12.

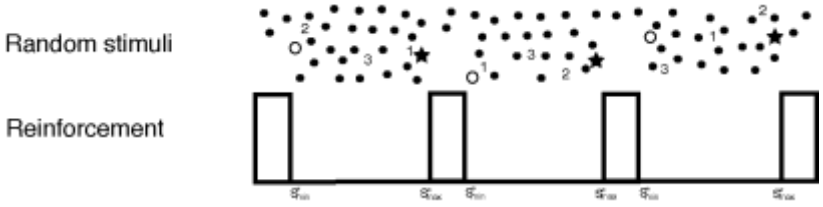



*Figure 10.13 Depiction of the conditions necessary for the extraction of $S_{min}$ and $S_{max}$ from all the stimuli which are otherwise independently and randomly occurring in the background. The particular stimuli which happen to be correlated with the moment before $S_{max}$ are depicted as stars, while particular stimuli that happen to be correlated with the moment most negatively correlated with $S^*_{max}$ i.e., $S^*_{min}$ are depicted as open circles. The vast array of various stimuli that are not correlated with specific positions across the interreinforcer interval are designated with solid dots; three are numbered. Sometimes these stimuli occur early in the IRI and sometimes they occur at other times.*

The most familiar stimulus correlated with a portion of the $S^*_{min}$ - $S^*_{max}$ gradient is the CS which is deliberately presented just before $S^*_{max}$ and at no other time, or the $S^D$ which is deliberately presented when $S^*_{max}$ will occur if a response occurs ($B_{max}$) and at no other time. Antecedent stimuli correlated with $S^*_{max}$ are illustrated by the stars in the above event stream in figure 10.13. The stars could be a green light which becomes a short delay CS, or a green key light which becomes an $S^D$, and they could be deliberately placed there by the procedure, or they could be a coincidental artifact of the procedure.

However, there can also be stimuli correlated with other portions of the $S^*_{min}$ - $S^*_{max}$ gradient. The most familiar examples of stimuli correlated with some other portion of the $S^*_{min}$ - $S^*_{max}$ gradient are an $S^\Delta$ stimulus in the Thorndikian paradigm, or a backward conditioning CS in the Pavlovian paradigm. Stimuli correlated with $S^*_{min}$ are illustrated with an open circle in Figure 10.13. The open circles could be a red light backward conditioning CS or an $S^\Delta$, and they could be deliberately placed there by the procedure or they could be a coincidental artifact of the procedure.

Any systematic correlation of specific stimuli with either the antecedent or final portions of the $S^*_{min}$ - $S^*_{max}$ gradient "conditions", "increases the salience of", "extracts", "selects", or "captures" them from the many other but randomly occurring background stimuli in each consecutive temporal portion of an interval.

The stimulus elements along the $S_{min}$ - $S_{max}$ gradient come to be able to control the behaviors reliably occurring in each respective position along an $S^*_{min}$ - $S^*_{max}$ gradient. That is to say that the procedures enable an extracted stimulus to semi-

permanently control the extracted behavior. A quasi homeostatic explanation would be that behavioral adjustments appropriate for preparing for condition "*c*" is "conditioned to" the stimulus extracted by position c-1 on the $S^*_{min}$ - $S^*_{max}$ gradient.

An explicit case of correlated stimuli in the $S_{min}$ - $S_{max}$ gradient is provided by an interfood clock schedule of reinforcement in which specific explicit stimuli are deliberately presented in each temporal portion of the $S^*_{min}$ - $S^*_{max}$ gradient. The typical procedure of presenting a bell immediately preceding meat powder, could be seen as a special case of an interfood clock schedule and extracts, selects, or conditions the final bell and the associated behaviors from the many randomly occurring stimuli and behaviors in the background of the conditioning apparatus at $S^*_{max}$.

An interest in the probability of behavior as a function of portion of the $S^*_{min}$ - $S^*_{max}$ gradient as controlled by the $S_{min}$ - $S_{max}$ gradient (the x axis in Figure 9.19) was one of the driving forces underlying research on schedules of reinforcement and the point of many of the figures in Ferster and Skinner. Hullian research had been focused on the factors determining the mean correct choice in a group of rats. Skinnerian research rejected the Hullian dependent measure as extraneous and inadequate. Rather Skinner focused on the moment-to-moment changes in the behavior of each individual. Skinnerian procedures were characterized as research on the free operant because the testing procedure could reflect the unconstrained moment-to-moment behavior as a function of the imminence of reinforcement of an individual organism.

The interfood clock procedure provides an explicit stimulus during each portion of the interfood interval and therefore enables an assessment of the behavior in each portion of that interval. The procedure provides for both free operant and free respondent research.

### 5. $t_{min}$ - $t_{max}$ Gradient

The temporal gradient is established and functions identically to the $S_{min}$ - $S_{max}$ gradient and is established for the same reason the $S_{min}$ - $S_{max}$ gradient is established. The only difference between temporal stimuli and typical stimuli is that temporal stimuli cannot be eliminated nor randomly ordered and that we have no idea of the actual nature of temporal stimuli nor how the sensory system "detects" time. Otherwise, they function exactly like arbitrary stimulus elements in the $S_{min}$ - $S_{max}$ gradient.

### 6. $B_{min}$ - $B_{max}$ Gradient

Arbitrary or "voluntary" behaviors which reliably occur at each position across the $S^*_{min}$ - $S^*_{max}$ interval come under the control of the stimuli correlated with each respective position of the $S^*_{min}$ - $S^*_{max}$ gradient which is to say that they are conditioned, extracted, or selected from the many other behaviors that randomly occur throughout the $S^*_{min}$ - $S^*_{max}$ interval essentially the same as arbitrary stimuli had been conditioned. These behaviors become the $B_{min}$ - $B_{max}$ gradient.

While the behaviors in the $B_{min}$ - $B_{max}$ gradient are arbitrary or voluntary, there are likely constraints imposed by the $S^*_{min}$ - $S^*_{max}$ gradient by way of its unconditional effect on behavior. Examples would be the non pecking behavior preceding a run of responding (i.e., at $S^*_{min}$) in a fixed ratio schedule, and the well-known difficulty of reinforcing approach and key pecking to terminate shock in pigeons. Key pecking is very unlikely to occur at $S_{max}$ when $S^*_{max}$ is shock.

It is important to emphasize at this point that the various behaviors controlled across the $S^*_{min}$ - $S^*_{max}$ gradient (i.e., the $B_{min}$ - $B_{max}$ gradient) are unlikely to all be identical to the behavior that occur at the $S_{max}$ - $S^*_{max}$ conjunction. Additionally, the outcome maintaining arbitrary behavior at $S^*_{min}$ is not the delayed positive effect of the subsequent $S^*_{max}$ (as will be subsequently discussed in section V). Rather the $B_{min}$ controlled by $S_{min}$ is conditioned by $S^*_{min}$. The behavior is not likely to be approach but rather is most likely to be avoidance.

#### 7. Instances of $B_{max}$

Finally, a monolithic or pseudo gradient containing only a single response class could be conceptualized for pedagogical purposes. It is illustrated by the lowest line in Figure 10.12. This "gradient" would be composed of only instances of $B_{max}$ rather than a gradient of different behaviors. This simplifies conceptualizing operant conditioning research which is focused exclusively on the occurrence of the specific behavior which immediately precedes $S^*_{max}$ (i.e., $B_{max}$).

Note that the traditional conceptualization of Thorndikian conditioning is that reinforcement stacks up $B_{max}$s earlier and earlier into the interfood interval until the point that the reinforcer becomes ineffective at doing so. From this perspective, earlier in the $S^*_{min}$ - $S^*_{max}$ interval is a dead zone where no conditioning can take place because it is too far removed from reinforcement.

The present bipolar conceptualization is quite different. Rather than a stack of $B_{max}$s extending back from the moment of reinforcement, the present conceptualization has a $B_{min}$ - $B_{max}$ gradient. The present view is not to say that every instance of a behavior across the $S_{min}$ - $S_{max}$ gradient must necessarily be different. Rather the present position asserts that not every behavior resulting from the conditioning procedure will necessarily be the same. The $B_{max}$ gradient is seen as a special case of the $B_{min}$ - $B_{max}$ gradient

### C. Outcomes of Short Time Scale Adaptation

#### 1. The Stimulus Control Over the Behavior Gradient When Antecedent Correlated Events Are Stimuli

Arbitrary antecedent stimuli in the $S_{min}$ - $S_{max}$ gradient are explicitly correlated with the elements in the $S^*_{min}$ - $S^*_{max}$ gradient in the Pavlovian conditioning paradigm. They are illustrated in the right frame of Figure 10.8. The dependent variable in Pavlovian procedure such as salivation is the $B^*_{min}$ - $B^*_{max}$ gradient or the $B^{*\prime}_{min}$ - $B^{*\prime}_{max}$ gradient (which is a reaction to the $B^*_{min}$ - $B^*_{max}$ gradient discussed

below). Both behavior gradients are under the control of the correlated arbitrary stimulus gradient ($S_{min}$ - $S_{max}$) or time ($t_{min}$ - $t_{max}$). A linear representation of the dependent variable in Pavlovian conditioning (i.e., the $B^*_{min}$ - $B^*_{max}$ and $B^{*'}_{min}$ - $B^{*'}_{max}$ gradient) is depicted in Figure 10.12. The special case of the control of an arbitrary green stimulus (the CS) over the behavior gradients (the CR) is illustrated in the right portion of Figure 10.12.

Unfortunately, the right frame of Figure 10.8 and Figure 10.10 did not have the capability of depicting the resulting stimulus control over the $B^*_{min}$ - $B^*_{max}$ or $B^{*'}_{min}$ - $B^{*'}_{max}$ gradient as an axis. That information will be presented on the *z*-axis in a subsequent figure depicting Pavlovian conditioning, ie., Figure 10.16.

### 2. The Stimulus Control Over the Behavior Gradient When Antecedent Correlated Events are Behavior

Antecedent behaviors of the $B_{min}$ - $B_{max}$ gradient are explicitly correlated with the $S^*_{min}$ - $S^*_{max}$ and $S_{min}$ - $S_{max}$ gradient in the Thorndikian conditioning paradigm. The dependent variable is the $B_{min}$ - $B_{max}$ gradient (or instances of $B_{max}$) under the control of the arbitrary stimulus gradient $S_{min}$ - $S_{max}$. A linear representation of the stimulus axis $S_{min}$ - $S_{max}$ and behavior gradient $B_{min}$ - $B_{max}$ (and instances of $B_{max}$) are depicted in Figure 10.12. The control of an arbitrary green stimulus (the $S^D$) over the operant behavior is illustrated in the right portion of Figure 10.12.

Unfortunately, the left frame of Figure 10.8, and Figures10.10 did not have the capability of depicting the resulting stimulus control over the $B_{min}$ - $B_{max}$ gradient or instances of $B_{max}$ in Thorndikian conditioning. That information will be presented on the z-axis in a subsequent figure depicting Thorndikian conditioning ie., Figure 10.16.

### 3. The Stimulus Control Over the Behavior Gradient When Antecedent Correlated Events are Time

x
x
x

## D. Conceptual Follow-Up: Overview / Review of the Correlational Space Schema

The four extracted or created arbitrary gradients ($S_{min}$ - $S_{max}$, $t_{min}$ - $t_{max}$, $B_{min}$ - $B_{max}$, and $B_{max}$) are designated with dotted lines in the gradients illustrated in Figure 10.12 because they are for the most part arbitrary. The $S^*_{min}$ - $S^*_{max}$ gradient as well as its two elicited behavior gradients are designated with asterisks and a solid or semi solid line because they are "fixed" behaviors or behaviors of long-term origin rather than arbitrary.

Figure 10.12 illustrates a specific stimulus (green light) along the $S_{min}$ - $S_{max}$ gradient coming to control specific behaviors along the three behavior gradients.

In sum, the $S^*_{min}$ - $S^*_{max}$ gradient as well as eliciting the $B^*_{min}$ - $B^*_{max}$ and $B^{*'}_{min}$ - $B^{*'}_{max}$ gradient also enables the $S_{min}$ - $S_{max}$ and $t_{min}$ - $t_{max}$ stimulus gradient to come to control the behavior gradients (i.e., $B^*_{min}$ - $B^*_{max}$, $B^{*'}_{min}$ - $B^{*'}_{max}$, $B_{min}$ - $B_{max}$ , and instances of $B_{max}$ .

# IV. Cubic Representation of the Correlational Space, the Procedures, and the Resulting Stimulus Control in Short Time Scale Adaptation

As is shown by Figure 10.12, Pavlovian conditioning and Thorndikian conditioning are inevitable outcomes of any procedure establishing an $S^*_{min}$ - $S^*_{max}$ gradient. As we will subsequently see, these procedures and results are well represented by a single cube, so that their commonalities are obvious, rather than by two separate squares (which implies that the two classes have nothing in common). Donahoe and Palmer label this coordinated approach "a unified reinforcement theory."

## A. Limitation Alert: Limited Graphical Capability

Unfortunately, full three-dimensional graphics with elements floating within a semi-transparent holographic cube where all the elements are perfectly visible as positions within a three-dimensional space and all functional relationships are illustrated with lines that can be easily seen as changing in three-dimensional space are not available. If such a figure were available, this section (i.e., Section IV) would be one paragraph long and would need only one figure. Unfortunately, you will have to construct the ideal figure yourself by observing, understanding, and combining various two-dimensional subsets of that ideal image presented across the next four pages. (Alternatively, get a clear plastic square and insert a rod through it, from the lower left front through to the upper right back, then write the labels for the axes on it to represent the three axes and then examine the internal rod with respect to the three axes from the various faces of the cube. It's not perfect but it at least gives you experience "handling" the functional relationships in three dimensions.) The following didactic may be more than necessary for some readers, less than enough for others.

## B. Conceptual Review: Common Procedure Underlying Short Time Scale Adaptation: The Instantiation of a Correlation

Recall the principle: if there is a difference in stimulus conditions associated with a difference in probabilities of functionally significant outcomes (reinforcement) then there will be a difference in behaviors.

First we begin with our fundamental correlational matrix illustrating the correlation that specifies the procedures in either Pavlovian conditioning or Thorndikian conditioning (first presented in Figure 10.7)

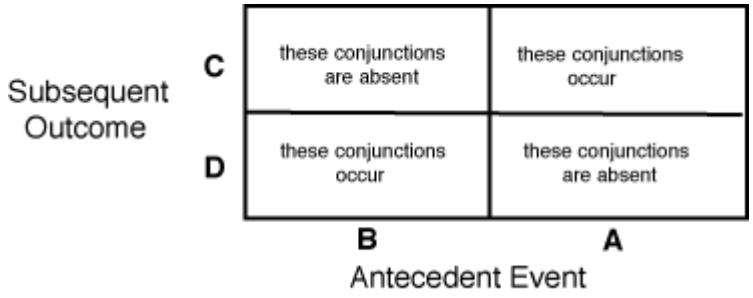



*Figure 10.14 A re-presentation of Figure 10.07. The conjunctions necessary for short time scale adaptation set into a 2x2 contingency table.*

## C. Conceptual Review: Specific Depictions for Pavlovian and Thorndikian Conditioning Procedures

We can then depict Thorndikian conditioning (antecedent behavior correlated with subsequent outcomes) or Pavlovian conditioning (antecedent stimuli correlated with subsequent outcomes) procedures as (Figure 10.15):

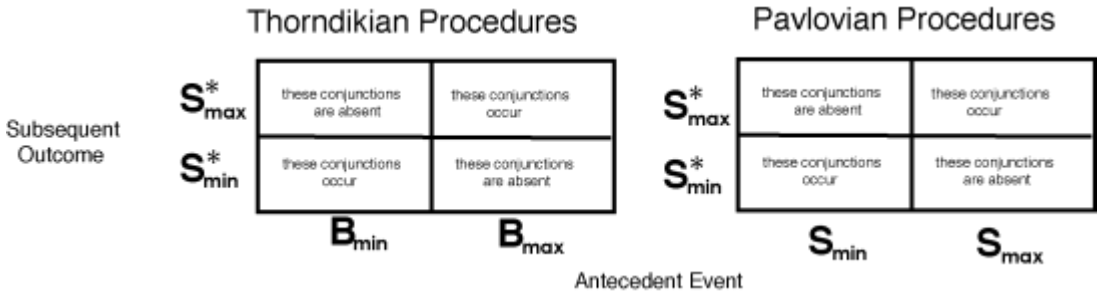



*Figure 10.15 The conjunctions necessary for Thorndikian and Pavlovian conditioning first presented in Figure 10.8 then detailed in terms of the gradients presented in Figure 10.12. In this case, their appropriate labels are used.*

At first blush, the two forms of Figure 10.7 that are depicted in Figure 10.15 appear to suggest that the two relationships are incommensurable – one represents behavior by reinforcer and cannot characterize the resultant stimulus control over behavior, while the other represents stimuli by reinforcers and cannot characterize the resultant stimulus control over behavior either. However, these two correlation matrices are actually two perspectives of the same underlying correlational cube that simultaneously depicts stimuli, behavior, and reinforcers and can therefore represent both procedural relationships and both stimulus control relationships simultaneously.

## D. Common Cubic Representation for Pavlovian and Thorndikian Procedures and Results

Displaying the seemingly different frames of Figure 10.15 in terms of a common cubic context in Figure 10.16 emphasizes the conceptual commonalities in these two procedures by showing that the two frames of 10.15 could be seen as two perspectives of a single cube, as represented in Figure 10.16.

### 1. Pavlovian and Thorndikian Procedures Mapped onto Two Orthogonally Related Two-Dimensional Surfaces

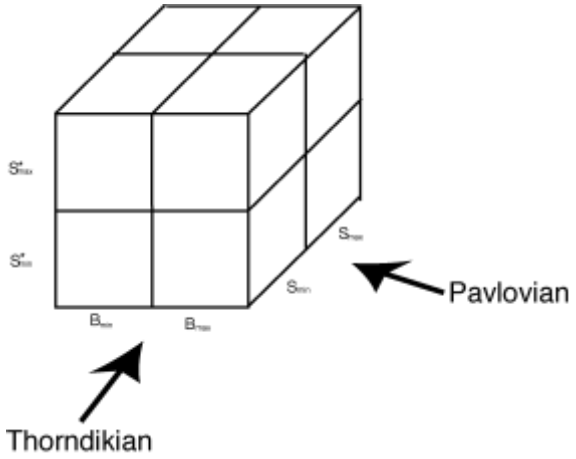



*Figure 10.16 The elements necessary for Thorndikian and Pavlovian conditioning set into a 2x2x2 contingency cube. The left frame of Figure 10.15 is the view seen on the front face, while the right frame of Figure 10.15 is the view seen on the right face.*

The Pavlovian conditioning perspective (i.e., right face perspective) is able to show that the instantiation of a correlation between the $S_{min}$ - $S_{max}$ gradient and the $S^*_{min}$ - $S^*_{max}$ gradient (its *x* and *y* axes) establishes control over the $B^*_{min}$ - $B^*_{max}$ gradient by the $S_{min}$ - $S_{max}$ gradient (its *x* and *z* axes) as was depicted in Figure 10.12. This behavioral result would be on the *x*-axis (left and right) and the *z*-axis (in and out) of this right face perspective of the cube. This procedure (*x* and *y* axes) and its result (*x* and *z* axes) is labeled Pavlovian conditioning.

Analogously, the Thorndikian conditioning perspective (i.e., the front face) is able to show that the establishment of a correlation between the $B_{min}$ - $B_{max}$ gradient and $S^*_{min}$ - $S^*_{max}$ gradient (its *x* and *y* axes) establishes control over the $B_{min}$ - $B_{max}$ gradient by the $S_{min}$ - $S_{max}$ gradient (its *z* and *x* axes) as was depicted in Figure 10.12. The results would be on the *z*-axis (in and out) and the *x*-axis (left and right) of this perspective of the cube. This procedure and its result is labeled Thorndikian conditioning.

### 2. Pavlovian and Thorndikian Results Depicted on Three Superimposed Two-Dimensional Surfaces

If we wanted to have the dependent variable portrayed as a change in the value of the behavior ($B^x_{min}$ - $B^x_{max}$) as a function of a change in the controlling stimuli ($S_{min}$ $S_{max}$), we could simply look at the cube in Figure 10.16 from the perspective that would put those axes where we want them. In Figure 10.16, it would be viewing the cube from the bottom. Alternatively, we could simply rotate the cube to put the $S_{min}$ $S_{max}$ gradient on the *x*-axis and the $B^x_{min}$ - $B^x_{max}$ gradient on the *y*-axis. We would see the cube from the perspective as shown in Figure 10.17. This is the stimulus control face of the cube.

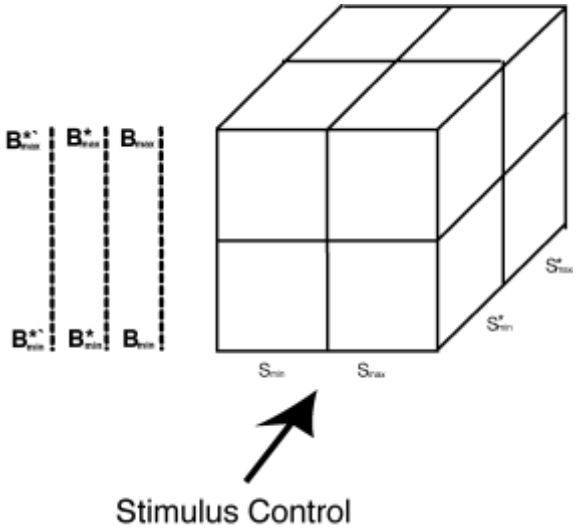



*Figure 10.17 This figure is the contingency cube depicted in Figure 10.16 rotated to put the change in behavior on the y-axis and the change in the controlling stimuli on the x-axis. Note that all three dependent variables are depicted across the y-axis and may not necessarily have the same scaling.*

### 3. Simplistic Idealized Procedures and Data

The unified three-dimensional representation of three orthogonal axes shown in figure 10.16 and 10.17 convey a conceptual structure. In the following figure (10.18) the Pavlovian and Thordikian procedural conjunctions and the resulting three behaviors ($B^*$, $B^{*'}_{max}$, and B) just so happen to correspond to a single diagonal vector through the cube. That is to say, the five axes are each scaled in such a way to make the data points in the eight functional relationships correspond to a single vector through the single three dimensional structure.

The rationale for the simplistic cubic representation of specially scaled data is that once the eight axes are integrated into a unified visual scheme, then the structure can more easily be conceptualized as a unified algebraic-like whole in which the behavior dimensions are not identical and are independent.

An advantage of this idealized conceptualization is that it implies that the behavioral adaptation is "tracking" in some way or is at least controlled by the conjunctions of events in the two procedures simultaneously. A second advantage

of the cubic representation is that it raises research questions in the form of "in what way are the four axes of Pavlovian procedures and data related to the four axes of Thorndikian procedures and data?" It would be of interest to formalize the relationships between the two "types" of learning and the their resulting data as a strategy to more adequately characterize short term adaptation.

### 4. Concrete Instantiation of a Three Dimensional Data Structure Simultaneously Representing Pavlovian and Thorndikian Procedures and Results

The display of changes in three simultaneous axes can be better understood by viewing the depiction of the resulting behavior within a cube from a perspective that allows the *x, y*, and *z* axes to be seen simultaneously. Two different diagonal perspectives of the information that was presented in Figures 10.16 and 10.17 is provided in Figure 10.18 below. The perspectives noted with the pointing fingers in the two frames of Figure 10.18 are the same behavior changes as a function of stimulus changes axes (the stimulus control information) as was depicted in Figures 10.17.

The wire in the two views of the cube below depicts the conjunctions of the antecedent events with the subsequent outcomes as well as the resulting behavior as a function of the stimulus gradient. It happens to be represented with an ogive curve for considerations outside the point of the present text.

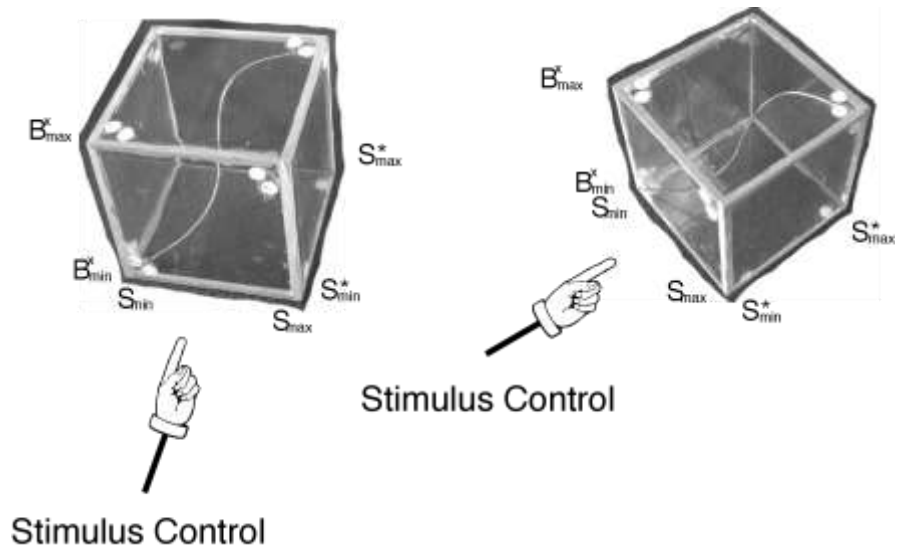



*Figure 10.18 Photographs of an actual transparent 3-dimensional cube depicting procedural and data elements from a diagonal perspective. The perspective indicated with a pointing finger is the stimulus control perspective and is that indicated in Figure 10.17.*

Note that this cubic representation is able to simultaneously depict the procedures and results of Thorndikian conditioning as well as the procedures and results of

Pavlovian conditioning (given that the eight functions were scaled to map onto a cube and to make a single vector appropriate).

Note that the idea for this unified conceptualization of short time scale adaptation was derived from John Donahoe's SQAB presentation. It is not suggested that he would agree with the positions taken in this chapter.

# V. Differences in Behavioral Output Predicted by a Bipolar Correlational and a Traditional View

It is important to note that the following comparison is between traditional and bipolar explanations for the behavior obtained from procedures with explicit stimuli correlated with the interreinforcer interval and from procedures where the reinforcement contingencies are repeatedly presented. An especially strong example of the preparation is a clocked fixed interval 60-sec schedule repeatedly presented in a concatenated procedure.

## A. Contrasting Ramifications of "Traditional Contiguity" Versus "Bipolar Correlation" Predictions for Short Time Scale Adaptation

Figure 10.19 illustrates the difference in a traditional contiguity view of reinforcement and a bipolar view. The difference in the views is especially obvious when comparing the explanation for the behavioral effect of a change from a baseline to a shorter or to a longer interfood interval.

While reading the following sections, be sure to note each factor on Figure 10.19.

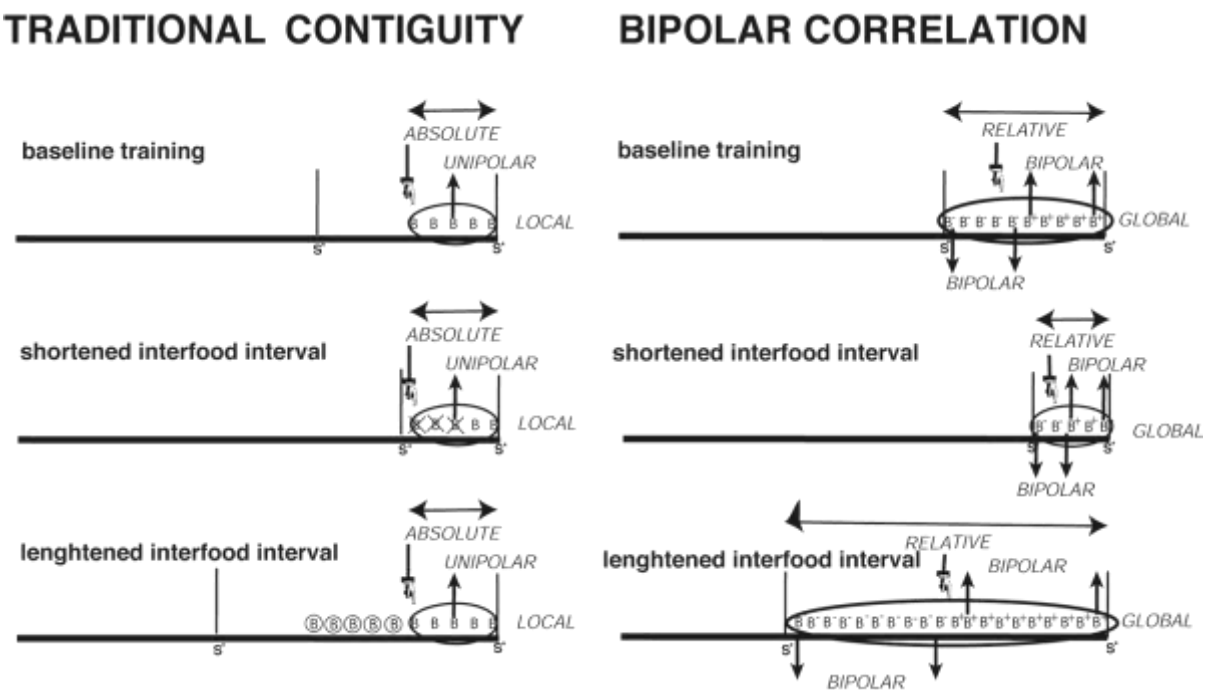



*Figure 10.19 The upper frame of the left frames illustrates three traditional functional properties of a reinforcer. First, it has an effect only locally as represented by the oval encircling only the behavior close to the reinforcer. Secondly, its effect spreads an absolute amount. There is no change in size of effect as the result of shortening or lengthening the interfood interval. Finally, its effect is unipolar. The effect of the reinforcement arrow only goes up. The right frames illustrate the bipolar view of the functional properties of a reinforcer. First it has a global effect from the best to the worse part of the schedule (this is illustrated by the circle of effectiveness change tracking the changes in the interfood interval; Secondly, specific effects spread a relative amount, such as half the distance to the polar opposite end of the schedule. This is illustrated by up arrows across the second half of the effect circle and, Finally, this effect is bipolar. For example, if the final portion of the schedule is food presentation, it increases the rate in the second half, while the early portion of the schedule is suppressive or at least controls some other behavior.*

### 1. Traditional Contiguity Based Conceptualization of Short Time Scale Adaptation

Traditional contiguity views of short time scale adaptation, or learning, emphasize the events close to, or contiguous with, a primary reinforcer. This is one way of accounting for the obvious fact that CRs or conditioned operants do not occur to every stimulus the organism ever experienced, and not every behavior that was ever reinforced occurs at its maximum rate at all times. This approach is exemplified by the notion of "discrimination and least effort". From this view, the behavior of an organism is effected by a pervasive suppressive effect of "effort." Unless otherwise acted upon, the organism would do nothing at all. In the context of no behavior, reinforcement acts to increase the probability of some specific minimally necessary behavior. Asymptotically, that behavior occurs only to stimuli that are virtually indiscriminable from the very specific immediate context of reinforcement. A temporary spread of effect occurs to similar stimuli (stimulus generalization). This effect disappears if the stimulus difference is within the

capacity of the organism to discriminate. For example it is believed that with perfect stimuli, eventually only a single response would occur in a fixed-interval schedule. The "rule" thought to describe behavior could be expressed "respond only to the very specific immediate antecedent to $S^*_{max}$, otherwise do nothing." This view can be evaluated by comparing the procedures represented in the left versus right columns of frames in Figure 10.19.

### a. Local

Traditional contiguity views conceptualize the effect of the reinforcer as occurring only to events very close to the reinforcer. The effectiveness of the reinforcer is quite limited in extent. Only events a few moments before the reinforcer are reinforced, after a delay of a few seconds a reinforcer's effectiveness is thought to be entirely lost(10 seconds for example). The remainder of the trial (earlier portions of the interreinforcer interval) is thought to be a dead zone where no learning process whatsoever happens. Given that a stimulus or response occurs earlier than the threshold between "local" and "other" it doesn't matter if they occurred 11 seconds, 1 week, or 10 years before the reinforcer. Responses in the dead zone would be strengthened only to the extent that the controlling stimuli were similar in some way to those of the reinforced response (i.e., stimulus generalization), and eventually temporal discrimination would reduce responding to those stimuli to zero or at least to the discriminative capacity of the organism.

### b. Absolute

Traditional contiguity views conceptualize the effect of the reinforcer as extending from the reinforcer earlier for some specific absolute time, or specific absolute number of responses, or specific number of stimuli.

For example, if reinforcement strengthened the last 10 responses even if to a lesser and lesser degree, then it would reinforce to some extent all behavior in a sequence of 3, 8, or 10 responses and only the last 10 responses in a sequence of 50, 100, or 1000 responses. The earlier responses in these latter cases would be strengthened only to the extent the controlling stimuli were similar in some way to those of the reinforced response (i.e., stimulus generalization) and eventually temporal discrimination would reduce that similarity to zero or at least to the discriminative capacity of the organism.

Delay of reinforcement is also thought to be absolute. For instance, if reinforcement strengthens any behavior within 10 seconds, albeit to a lesser and lesser degree, then a response 0 seconds before the reinforcer, would be strongly reinforced, while a response preceding the reinforcer by 10 seconds would be only minimally reinforced, and any response prior to 10 seconds before the reinforcer would not be reinforced at all. Only the last 10 seconds of an interval would be expected to control responding regardless of whether the overall interval were 30, 60, 240, or 2000 seconds. The earlier response units in this latter case would be strengthened only to the extent that the controlling stimuli were similar in some

way to those in the final 10 second portion of the trial, and eventually temporal discrimination would reduce that effect to zero.

#### c. Unipolar

Finally, traditional contiguity views of reinforcement conceptualize the effect of the reinforcer or subsequent outcome as a strengthening effect only. No other effects can be accounted for. For example, if robust responding is maintained during the last 50 seconds of a 200-second interval, then when the interval is reduced to a 60-sec interval, robust responding must continue to be maintained to the entire final 50 seconds because there is no suppressive effect available.

### 2. The Correlation-Based Bipolar Conceptualization of Short TIme Scale Adaptation

The bipolar correlational paradigm differs radically from a traditional contiguity notion of reinforcement. A bipolar correlational view takes a substantially different perspective on each of the previous three issues. While reading the following sections, be sure to note each factor in the right frames of Figure 10.19 and be sure to compare and understand the difference between a traditional conceptualization (left portion of the figure) and a bipolar conceptualization (right portion of the figure).

#### a. Global

An aspect of reinforcement, from a correlational view, would be that some effect would be expected to be global or across the entire $S^*_{min}$ - $S^*_{max}$ gradient, rather than for only a short period immediately preceding the reinforcer with a repeatedly presented short trial. Recall that in the bipolar view, the $S^*_{min}$ - $S^*_{max}$ gradient extends from $S^*_{min}$ where the reinforcer is the least imminent or least likely which is maximally negatively correlated with the reinforcer; to $S^*_{max}$ where the reinforcer is maximally imminent or maximally likely. From a correlational perspective, both ends of the $S^*_{min}$ - $S^*_{max}$ gradient are active in controlling behavior, albeit not necessarily the same behavior nor the same vector nor the same absolute strength.

Some maximum absolute limit to the global effect is clearly necessary. Outside a procedure with relatively short trials, this global effect would be expected to be quite small. It would seem safe to presume that an event perfectly negatively correlated with the subsequent $S^*_{max}$ 1 month or 1 year before a reinforcer could not be effective as $S_{min}$. A principled specification of the extent of the $S^*_{min}$ - $S^*_{max}$ interval is an essential obligation of the bipolar view.

#### b. Relative

A correlation view of reinforcement would also expect that events would be equally effective to the extent they were equal ratios across the axes of the

correlation. For example, a 1-second trial stimulus in a 100-second interfood interval (IFI) would be expected to control behavior similarly to a 10-second trial stimulus in a 1000-second IFI. This type of effect is totally inconsistent with traditional absolute contiguity views. Note that the notion of relative contiguity changes a contiguity model into a correlational model. Again it's important to note, that outside the traditional repeated trials procedure with relatively short trials, this effect could be quite small or nonexistent.

From the correlation-based bipolar perspective, it would seem that "relative imminence of reinforcement" would be a better descriptor than "the interreinforcer interval" for the period between reinforcers in a concatenated trials procedure because interreinforcer interval implies some absolute duration and an absolute effect.

Some maximum absolute limit to the relative effect is clearly necessary. Outside a procedure with relatively short trials, this relative effect would be expected to be quite small. It would seem safe to presume that a 10,000 second stimulus in a one million second trial would not be as effective as a one second stimulus in a 100 second interreinforcer interval. A principled specification of the extent of the effective $S^*_{min}$ - $S^*_{max}$ interval is an essential obligation of the bipolar view.

### c. Bipolar

A final aspect of a correlational view of reinforcement would be that the effect of reinforcement across an interreinforcer interval would be bipolar, that is that positive correlations (e.g., the latter portion of a fixed IFI or higher probability of reinforcement) would result in one behavior (e.g., approach) while negative correlations (e.g., the antecedent portion of a fixed IFI or lower half of the probabilities of reinforcement) would exhibit some other or even opposite behavior (e.g., avoidance), and that the relative strengths of those conditioned behaviors are a function of the relative strengths of those correlations. For example, if a 60-sec FI maintains behavior for 30 seconds, then shifting the schedule to an FI-30 would not maintain responding at the beginning of the FI 30-sec (see the upper and center frame of the left column of Figure 10.19). Absent the suppressive process in the bipolar view, a traditional contiguity view would be hard pressed to explain the loss of behavior 30 seconds prior to a reinforcer in an FI 60-sec changed to an FI 30-sec. A principled specification of how to specify the value of $S_{min}$ with respect to $S_{mid}$ and $S_{max}$ is an essential obligation of any general process learning theory. Similarly, the additional responding in the early portion of an FI 120-sec after changing from an FI 60 sec must have a principled explanation (see the bottom left frame in Figure 10.19).

### B. Graphically Representing Behavior Predicted by a Bipolar Correlation View Across Experience and the Relative Imminence of Reinforcement Gradient

A 3-dimensional stylized depiction of the expected acquisition and asymptote or equilibrium of behavioral adaptation as a function of the $S^*_{min}$ - $S^*_{max}$ interval and experience has been used in an earlier portion of this text (Figure 9.21) to illustrate other issues. It is re-presented below as Figure 10.20.

The figure portrays the hypothetical behavior obtained to an interfood clock across a fixed interfood interval with increasing experience. In this procedure, explicit, salient, discrete stimuli are deliberately correlated with each portion of the interfood interval and create an explicitly signaled $S^*_{min}$ - $S^*_{max}$ gradient. The positive or negative value of these various clock stimuli ( ie. the $S_{min}$ - $S_{max}$ gradient) can be assessed by documenting whether the clock stimuli control the behavior of turning them on (i.e., are positive reinforcers), or control the behavior of turning them off (i.e., are negative reinforcers).

The surface of the figure portrays the normalized change in the "value" of these clock stimuli by indexing the rate of turning on or turning off the clock stimuli as a function of both the time in an interfood interval (left to right), and with increasing experience (front to back). It is essential to note that the positive and negative values of the function in this figure have been normalized on the *y*-axis. The positive and negative "values" are unlikely to be perfectly symmetrical.

In the hypothetical data illustrated on the first exposure to a 60-sec trial with clock stimuli, the pigeons did nothing. This is depicted as a straight line from left (the start of the trial) to right (the end of the trial). There is no change in its y-axis value. The next exposure is represented by the next consecutive line behind the first line. The data from each successive trial is presented as each consecutive left to right line proceeding back the *z*-axis. The figure indicates that after 7 trials the very beginning of the interfood interval begins to become negative (the stimuli are negative reinforcers) while the very end of the interfood interval begins to become positive (the stimuli are positive reinforcers). This means that the pigeon turned off the first stimulus and turned on the last stimulus. This trend continues until the beginning of the interfood interval is maximally negative ($S^*_{min}$ controling $B_{min}$), while the end of the interfood interval is maximally positive ($S^*_{max}$ controling $B_{max}$). This means that at asymptote (the back edge of the surface) the pigeon initially turned off the stimuli at a very high rate that decreased to the middle portion of the interval. The pigeon then began turning on the stimuli at a higher and higher rate with the maximum rate at the end of the interval. Recall that this figure normalizes the negative and positive values.

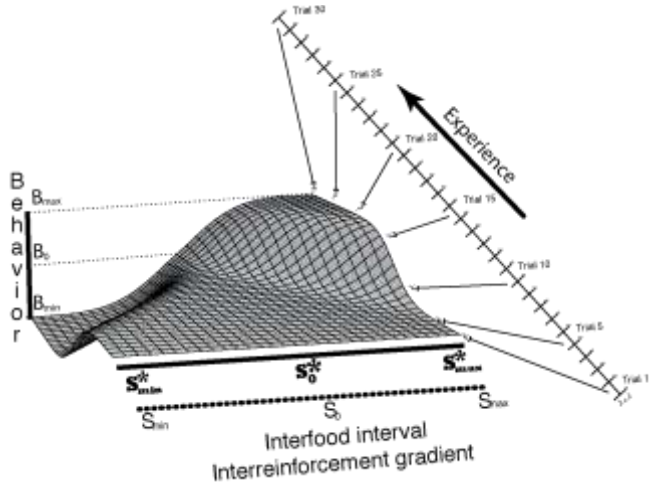



*Figure 10.20 This figure is a representation of Figure 9.21. This figure depicts two behavior dynamics simultaneously. The procedure is a fixed-time schedule. The first trial is depicted from the front left across to the front right along the first left to right line. The second line presents the behavior in the second trial, the third line is the third trial and so on. In this specific example, the first seven trials have no change on the y-axis and indicate no behavior. For the next few trials, the behavior to the initial portion of the trial decreases more and more and that decrease extends further into the interval with increasing experience. At the same time the rate to the final portion of the trial increases more and more and that increase occurs earlier in the interval. This trend continues until the synchronous average of the behavior across the interval is ogival at asympt*ote *as is portrayed at the rear of the figure.*

### C. A Speculative Homeostatic Conceptualization of Short Time Scale Adaptation

Although unnecessary, the factors determining short time scale adaptation could be cast within an internal motivating disturbance/resolving process conceptualization. The most familiar example of this type of conceptualization was advanced by Clark Hull in his need reduction formulation of learning. In his system, growing biological needs provided the motivation or motive force, while consummatory behavior provided the need reduction or resolving process that in turn reinforced or strengthened the class of behavior immediately preceding that consumption.

The comfort, albeit inessential, provided by a motive force/resolving process approach has frequently led to couching short time scale adaptation within a homeostatic framework when a simple externalistic functional analysis feels unsatisfying.

If it were considered a desirable goal, the present correlational basis of short time scale adaptation could be conceptualized as homeostatic. It should be noted, however, that the internal homeostatic narrative comes from the known external functional relationships not the other way around.

Given that a reinforcer such as food presentation occurs discreetly rather than continuously, and also occurs in concatenated trials, there would be occasions of $S^*_{max}$ and the resulting obligatory occasions of $S^*_{min}$.

The separation between $S^*_{min}$ and $S^*_{max}$ would necessarily establish an $S^*_{min}$ - $S^*_{max}$ gradient, vector, or axis across that dimension of separation. The $S^*_{min}$ - $S^*_{max}$

gradient would elicit a gradient of behavioral adjustments ($B^*_{min}$ - $B^*_{max}$) and their compensatory adjustments ($B^{*'}_{min}$ - $B^{*'}_{max}$). The $S^*_{min}$ - $S^*_{max}$ gradient could be said to control or elicit this series of different behavioral adjustments in order to attain the asymptotic or "appropriate" homeostatic behavior to each specific portion of the $S^*_{min}$ - $S^*_{max}$ gradient. The behavior under neutral conditions could be labeled $B^*_{neutral,}$ and the discrepancy between the asymptotic $B^*_{min}$ - $B^*_{max}$ gradient and $B^*_{neutral}$ at each point along the gradient could be defined as the underlying motive force. The behavioral adjustment to that discrepancy could be cast as the resolving process. The reduction in the discrepancy between the behavior appropriate to a situation (e.g., $B^*_{max}$) and the baseline or neutral behavior in that situation ($B^*_{neutral}$) would enable the arbitrary stimulus element (e.g., $S_{max}$) to come to control the "innate" behavior for that specific situation, (e.g., $B^*_{max}$ and $B^{*'}_{max}$) at the ideal time thus reducing the after the fact behavioral adjustments to zero. This control of the ideal behavioral adjustment ahead of time is labeled conditioning just as is the occurrence of any CR to a CS. The $S^*_{min}$ - $S^*_{max}$ gradient would condition behavior to the time, and stimuli which were correlated with each point along that $S^*_{min}$ - $S^*_{max}$ gradient. It would be as if smaller variances in the subsequent obligatory behavioral adjustments allowed the minimization of some aversive aspect of those after the fact behavioral adjustments. That is to say that salivation before the meat powder in the mouth would be better than only after the meat powder presentation.

Homeostatic-driven conditioning across the $S^*_{min}$ - $S^*_{max}$ interval would: first depend on the magnitude of the required behavior adjustment in each portion of the interval. The growth function of acquisition would approach its asymptote or limit in each portion of the interval according to the salience of the stimuli and the effectiveness of the subsequent outcome.

In the Pavlovian conditioning case, given the occurrence of an $S^*_{max,}$ and its resulting $S^*_{min}$ - $S^*_{max}$ gradient, in the absence of any conditioning, there would be substantial variance between the $B^*_{neutral}$ and the various specific obligatory ideal adjustments instantiated as the $B^*_{min}$ - $B^*_{max}$ and $B^{*'}_{min}$ - $B^{*'}_{max}$ gradients. However, if there were a correlation between $S_{min}$ - $S_{max}$ (or $t_{min}$ - $t_{max}$) and $S^*_{min}$ - $S^*_{max,}$ then substantial variance between the $B^*_{neutral}$ and those ideal gradients could be eliminated by learned adjustment behaviors. This type of effect could be labeled "the $S_{min}$ - $S_{max}$ (or $t_{min}$ - $t_{max}$) elements signal respective elements in the $S^*_{min}$ - $S^*_{max}$ gradient and therefore provide for the optimization of behavior to each point in the $S^*_{min}$ - $S^*_{max}$ gradient.

In the Thorndikian conditioning case, the acquired behavior of the $B_{min}$ - $B_{max}$ gradient can be seen from two perspectives. First is that behavior which is correlated with specific segments of the $S^*_{min}$ - $S^*_{max}$ gradient comes under the control of, or is conditioned to those specific segments of the $S_{min}$ - $S_{max}$ gradient. For example, a behavior correlated with $S^*_{max}$ will occur in the presence of $S_{max}$, and a behavior correlated with $S^*_{min}$ will be conditioned to $S_{min}$.

From this perspective, the $S_{min}$ - $S_{max}$ gradient reduces the variance in the $B_{min}$ - $B_{max}$ gradient. This type of effect could be labeled "the $S_{min}$ - $S_{max}$ elements signal the respective portions of the $S^*_{min}$ - $S^*_{max}$ gradient and therefore provides for the optimization of the acquired behavior to the various portions of the $S^*_{min}$ - $S^*_{max}$

gradient. In the case of an arbitrary behavior gradient, for this explanation to be relevant, the homeostatic process would have to be a given and some chain of arbitrary behaviors which could be optimized would be necessary.

The alternative perspective for the Thorndikian conditioning case is the effect of $B_{max}$ on the variance in the occurrence of $S^*_{max}$. If the correlation between $B_{max}$ and $S^*_{max}$ is via a dependency, then the occurrence of $B_{max}$ reduces the delay to, as well as the variance in, the occurrence of $S^*_{max}$. This type of effect could be labeled "the $S_{min}$ - $S_{max}$ elements enable the reduction in the delay to, as well as the variability of, the occurrence of the reinforcer."

The homeostatic process could be extended to the effectiveness of prior ontogenic and phylogenic experience. That is to say, the behavioral adjustments required by various events could be decremented across multiple time scales. Additional covariates could come from other prior short time scale adaptations or from prior medium-term or even prior long-term adaptations. For example, the amount of eye squinting that must be learned ontogenically would be reduced by a phylogenically-established pupillary contraction to bright light. In this way, the optimum time scale of adaptation for each functional relationship would be established across evolution.

It would be expected that the contingencies between one set of gradients could alter the contingencies between other gradients. Two notable examples would be elements in a Thorndikian (Pavlovian) contingency de-correlating elements in a Pavlovian (Thorndikian) contingency or the blocking of the control exerted by one contingency by the conditioning of another. Given that a behavioral adjustment was under the control of a reliable stimulus, then there would be little behavioral adjustment or motive force left to resolve and therefore no conditioning.

### D. Summary of the Determinants of Short Time Scale Adaptation

Short time scale behavioral adaptation is the result of exposure to the four components of a correlation. That is: 1) an $S^*_{min}$ - $S^*_{max}$ gradient, 2) an $S_{min}$ - $S_{max}$, $t_{min}$ - $t_{max}$, and/or a $B_{min}$ - $B_{max}$ gradient, 3) reduced variance in the reactions to $S^*_{min}$ - $S^*_{max}$ gradient as a function of the predictor, and, 4) exposure to a sufficient range of conjunctions. As the result of exposure to that correlation, stimuli along the $S_{min}$ - $S_{max}$ gradient come to control the respective behaviors along three behavior gradients.

The repetitive presentation of a functionally significant event such as food or shock in concatenated trials creates a gradient from the event most positively correlated with that functionally significant event ($S^*_{max}$) to the event most negatively correlated with that functionally significant event ($S^*_{min}$) (typically, but not necessarily, back across time).

That $S^*_{min}$ - $S^*_{max}$ gradient elicits or induces the $B^*_{min}$ - $B^*_{max}$ and $B^{*'}_{min}$ $B^{*'}_{max}$ gradient as the result of long-term or evolutionary adaptation. The $S^*_{min}$ - $S^*_{max}$ gradient establishes control over the behavior along the $B^*_{min}$ - $B^*_{max}$ and $B^{*'}_{min}$ - $B^{*'}_{max}$ gradient by stimuli which are correlated with each respective portions of the $S^*_{min}$ - $S^*_{max}$ gradient (i.e., the $S_{min}$ - $S_{max}$ and $t_{min}$ - $t_{max}$ gradient). This is the control over fixed behaviors by arbitrary stimuli and is labeled Pavlovian conditioning.

The $S^*_{min}$ - $S^*_{max}$ gradient also comes to establish an arbitrary behavior gradient ($B_{min}$ - $B_{max}$) by virtue of the correlation of various arbitrary or at least relatively arbitrary behaviors with respective portions of the $S^*_{min}$ - $S^*_{max}$ gradient. The $S_{min}$ - $S_{max}$ gradient comes to control the expression of those respective behaviors in the $B_{min}$ - $B_{max}$ gradient. This is the control over arbitrary behaviors by arbitrary stimuli and is labeled Thorndikian conditioning.

The function relating behavior to the $S^*_{min}$ - $S^*_{max}$ interval is, at this point, expected to be an ogive or a Gaussian cdf. This shape would follow if conditioning were a function of Weber's Law and the discrepancy between the alternatives. Characterizing its final form is pending

# VI. The Bipolar Correlational Model of Learning and Mainstream EAB

## A. Corroboration for Bipolar Correlational Model

### 1. Bipolar Distribution of Behavior Because $S_{min}$ (via $S^*_{min}$) Controls Elicited Escape Behavior and $S_{max}$ (via $S^*_{max}$) Controls Elicited Approach

The $S_{min}$ - $S_{max}$ gradient generally comes to control a bipolar gradient of behaviors because the milieus of induced behaviors at the opposite ends of the $S^*_{min}$ - $S^*_{max}$ gradient are different; that is to say that the opposite behavioral adjustments are controlled by the opposite ends of the gradient. For example, Hurst and Jenkins pointed out that pigeons leave an area signaling a long delay to food and approach signals of a short delay to food.

### 2. Bipolar Distribution of Behavior Because $S_{min}$ (via $S^*_{min}$ ) is a Negative Reinforcer While $S_{max}$ (via $S^*_{max}$ ) is a Positive Reinforcer

For example, Dinsmoore has shown that pigeons will turn off cues indicating relatively long delays to food and will turn on cues indicating relatively short delays to food.

### 3. Bipolar Distribution of Behavior Because the Behavior Gradient is Composed of Elements Across a Behavior System

The various behaviors along the gradient from $B^*_{min}$ to $B^*_{max}$ and $B^{*\prime}_{min}$ $B^{*\prime}_{max}$ are the organized sequences of behaviors discussed under "behavior systems" by Timberlake. His perspective explicitly acknowledges the fact that long-term contingencies (evolution) have established the behavioral elements for the behaviors which occur to the various positions along the $S^*_{min}$ - $S^*_{max}$ gradient.

#### 4. Bipolar Distribution of Behavior Because the Bipolar Gradient is Composed of Interim, Facultative, and Terminal Behaviors

Staddon demonstrated three distinct behaviors across an interfood interval. His labels for behaviors along the $S^*_{min}$ - $S^*_{max}$ gradient would be "interim" for $B^*_{min}$ and $B^{*\prime}_{min;}$ "facultative" for $B^*_{mid}$ and $B^{*\prime}_{mid}$ or the behaviors that occur midway through the $S^*_{min}$ - $S^*_{max}$ gradient; and "terminal" for $B^*_{max}$ and $B^{*\prime}_{max}$.

#### 5. Bipolar Distribution of Behavior Because a Lateral Inhibition-like Process Would Sharpen Stimulus Control Across a Gradient and Therefore, Provide For the Optimization of Behavior

Lateral inhibition is a common process in neural structures and in perceptual systems across organisms. If lateral inhibition occurs frequently throughout the nervous system, and is seen in many perceptual phenomena then it is not much of a reach to also expect it in the expression of short time scale adaptation. It could be hypothesized that a lateral inhibition like effect would sharpen the differentiation of the negative from positive elements (i.e., $B^*_{min}$ vs. $B^*_{max}$) of a schedule and that that could provide for the optimization of behavior. As a result, it would be expected to provide relative reproductive success.

### B. The Normal Science Challenges Facing the Bipolar Correlational Model of Behavior

#### 1. The Relative Value of the Behavior to Stimuli Positively and Negatively Correlated with the Subsequent Outcome

The two extremes of behavior (i.e., $B^x_{min}$ and $B^x_{max}$) are roughly analogous to mirror images. The stronger the response at $S^*_{max}$ (e.g., "approach"), the stronger the "opposite" vector is expected to be at $S^*_{min}$ (e.g., "avoidance"). Figure 10.20 shows a **normalized** figure where the negative and positive portions of the figure were equalized. The actual measured magnitudes are unlikely to be precisely the same and the behaviors are unlikely to be precisely the opposite. For example, the $B^x_{min}$ that goes with jumping 6 inches toward the food tray ($B^x_{max}$) is unlikely to be digging a 6-inch hole in the back of the chamber. Rather it may be pacing or doing nothing. If $B^x_{max}$ is pecking at 5 pecks per second, it's unlikely that wing flapping at $S_{min}$ would occur at 5 flaps per second.

Part of the asymmetry is due to the asymmetrical control exerted by the two ends of the gradient. While food pulls or attracts behavior and therefore strongly controls a relatively narrow vector (analogous to the vector of a pulled wagon), the absence of food pushes behavior and therefore poorly controls a relatively broad vector (analogous to the vector of a pushed wagon). Additionally, with longer and longer interfood gradients, it is increasingly likely that the interval would break up into sub-gradients under other control.

But, in the end, it may serve some purpose to define $B_{min}$ and $B_{max}$ as equal and opposite and thereby have some metric of relative or subjective magnitude and vector.

### 2. The Momentum of The Behaviors ($B^x_{min}$ and $B^x_{max}$) at the Initial ($S^*_{min}$) and Terminal ($S^*_{max}$) Ends of the Bipolar Gradient

The present model would suggest that both $B^x_{min}$ and $B^x_{max}$ would be high momentum behavior while midway between $S^*_{min}$ and $S^*_{max}$ a low momentum behavior would occur.

### 3. The Form of the Bipolar Behavior Function Across the Relative Imminence of Reinforcement Gradient

Figure 10.20 depicts maximum "approach" at $S^*_{max}$ and maximum "anti approach" at the point most negatively correlated with $S^*_{max}$. Additionally, that figure portrays the limbs of the function as negatively accelerated.

There is conflicting evidence as to whether the obtained behavior shows negative or positive acceleration as it approaches $S_{max}$ - $S^*_{max}$ (and elapses toward the middle of the $S_{min}$ - $S_{max}$ gradient). The different functions are depicted in Figure 10.21.

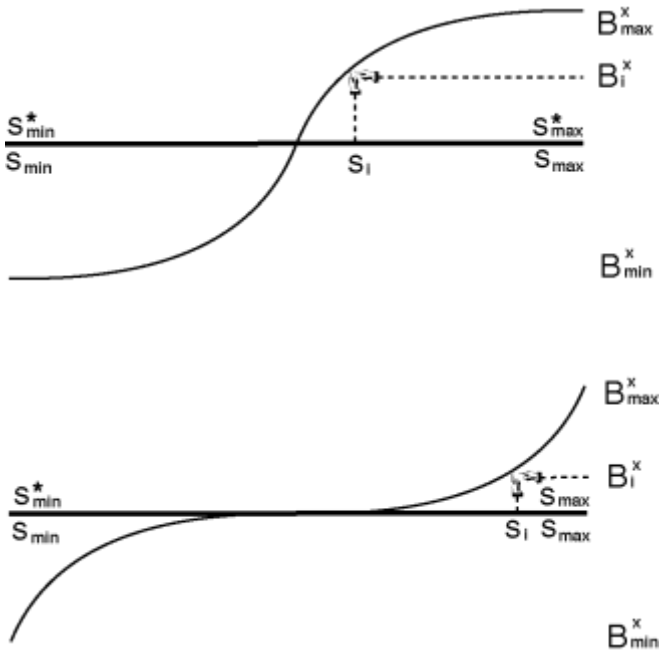



*Figure 10.21 Both segments of the figure depict $B^*_{max}$ at $S^*_{max}$ and $B^*_{min}$ at $S^*_{min}$. The upper and lower figures differ in the form of the function connecting those two points. If only a single function is appropriate, its form awaits further research.*

### 4. Higher-order Bipolar Effect

In a single stimulus long delay trial, it would be expected that the onset of the trial stimulus would exhibit inhibition of delay. That is to say, that in addition to an $S^*_{min}$ - $S^*_{max)}$ bipolar function, the trial stimulus would itself also exhibit a bipolar effect due to its onset signaling a negative correlation with $S^*_{max}$

## C Challenges to the Bipolar Correlational Model and Speculative Explanations for Anomalous Results

The resolution of these issues is an obligation of the bipolar correlational view. These issues are the first priority of any normal science based on this view.

### 1. Partial Reinforcement "Stronger" Than Continuous Reinforcement

The behavior that is reinforced may shift to more molar units for example what is initially a single peck may become an extended burst of pecking or even constant pecking across extended intervals.

### 2. Absence of Strong Conditioning at $S^*_{min}$

Over trials, a wide variety of behavior and stimuli may occur at $S^*_{min}$ and as a result, fail to provide the prerequisites of a correlated behavior or correlated stimulus.

A second potential factor contributing to the weak conditioning at $S_{min,}$ may be that typically chosen dependent variables may not effectively compete with other "avoidance" or "escape" behaviors. For example, a key peck that turns off a stimulus associated with $S_{min,}$ may not predominate over simply turning away or eye closing.

### 3. Absence of Both Strong Pavlovian and Strong Thorndikian Conditioning at $S^*_{max}$

A strong $S_{max}$ - $S^*_{max}$ correlation and its resulting strong $S_{max}$ - $B^*_{max}$ and $S_{max}$ - $B^{*'}{}_{max}$ correlation may block the conditioning of a strong $B_{max}$ at $S_{max}$. Contrariwise, a strong $B_{max}$ - $S^*_{max}$ correlation and a strongly conditioned $B_{max}$ at $S_{max}$ may block the conditioning of a strong $B^*_{max}$ or $B^{*'}{}_{max}$ response at $S_{max}$. Once a full behavioral adjustment occurs, the machinery by which further conditioning occurs is absent.

# CHAPTER 11

# Conceptual Structure for the Experimental Analysis of Behavior

## I. Conceptual Precursor: Value of Conceptual Structures

A. Dimensioning rationale
B. Instance selection rationale

## II. Structure with Which to Conceptualize Short time scale Adaptation

A. Molarity by time scale structure for science
B. Arbitrariness of elements by relative imminence of reinforcement, by complexity of concurrency structure for short time scale adaptation
    1. Overview of structure
    2. Axis 1: arbitrariness of elements in the contingency dimension
        a. Functional relationships between arbitrary stimuli and fixed responses as the result of fixed reinforcers (Pavlovian conditioning) [S-B*-S*]
        b. Functional relationships between arbitrary stimuli and arbitrary responses as the result of fixed reinforcers (Thorndikian conditioning) [S-B-S*]
        c. Functional relationships between sets of arbitrary stimuli and sets of arbitrary responses as the result of fixed reinforcers (equivalence relations) [$S_i$ - $B_j$ S*]
        d. Functional relationships between arbitrary stimuli and arbitrary responses as the result of arbitrary reinforcers (conditioned reinforcement and higher-order conditioning) [S-B-S]
        e. Functional relationships between sets of arbitrary stimuli and sets of arbitrary responses as the result of sets of arbitrary reinforcers (e.g., language) [$S_i$ - $B_j$ $S_k$]
    3. Axis 2: relative imminence of reinforcement dimension
    4. Axis 3: complexity in concurrency dimension
        a. Single contingency (no concurrency)
        b. Simple concurrent schedule
        c. Dynamic concurrent schedule
        d. Dynamic concurrent schedule with shift cost
        e. *N* alternative concurrent schedule
        f. Concurrent chains schedule
C. Linear schema for dimensions involved in short time scale adaptation
D. Unified graphic for dimensions resulting in short time scale adaptation

E. Requisite elements necessary for short time scale adaptation
1. Requisite elements necessary for Thorndikian adaptation
a. Discriminably different antecedent events (behaviors)
b. Functionally different subsequent outcomes
c. Variance in the behavior around $y'$ less than around $\bar{y}$
d. Sufficient exposure to alternatives
2. Requisite elements necessary for Pavlovian adaptation
a. Discriminably different antecedent events (stimuli)
b. Functionally different subsequent outcomes
c. Variance in the behavior around $y'$ less than around $\bar{y}$
d. Sufficient exposure to alternatives

## III. Conceptual Reflection: Structure for Conceptualizing Short Time Scale Adaptation

# CHAPTER 11

# Conceptual Structure for the Experimental Analysis of Behavior

## I. Conceptual Precursor: Value of Conceptual Structures

Recall that the experimental analysis of behavior involves the measurement and explanation of moment-to-moment response dimensions from an individual as a function of changes in defined and measured stimulus dimensions, that show short time scale hysteresis.

The following structure (Figure 11.1) is the postulation of the fundamental dimensions underlying short time scale behavioral adaptation. The structure provides a coherent single framework for the great variety of research in EAB. The dimensions are based on an externalistic perspective but could also be seen from an internalistic perspective. That is to say, the structure can most appropriately be seen to contain procedures that produce changes in dependent variables. But, the structure could also be seen to specify procedures that produce the referents for inferred things such as "thinking" (cognitive psychology) or "connections" (neuroscience).

It would be expected that various relationships with the same coordinates in the organizational scheme would function similarly, that relationships with the same value on a dimension would function similarly with respect to that dimension, and that the interaction of functional relationships would have some commonality with the spatial relationship in the model. The structure could also be seen as providing a framework with which functional relationships could be generalized. However, each of those properties is an empirical question.

### A. Dimensioning Rationale

To the degree that the dimensions of the organizational structure represent functionally important dimensions in nature, then understanding this structure of research activities will allow us to more easily understand the determinants of behavioral adaptation and to better generalize those determinants to new situations. The goal is to conceptualize axes that account for the largest sources of variance, with the fewest and simplest continua. An additional benefit of the dimensioning goal is that organizational dimensions may help us identify and understand previously unknown and unsuspected relationships.

### B. Instance Selection Rationale

The particular instance on a dimension or specific behavioral phenomenon that is selected to be researched must produce orderly data, and those functional relationships must be revealing of at least some important aspects of the general process underlying short time scale behavioral adaptation as a minimum, and ideally result in substantive gain in understanding the whole structure. Beyond that, it may be as simple as what an individual researcher enjoys. It would seem that virtually any research choice could result in meaningful gain.

Different instances on a dimension may:

1. all function identically, in which case there are no intrinsic partitions or subsets and the study of any is as good as any other;
2. all function differently, in which case all of the different partitions or subsets must be studied and the selection of any is as good as any other, as long as many different instances are investigated. With any luck, information useful in creating a better and more integrating structure would result
3. the whole may be more than the sum of the parts, and the resulting paradigm would be obligated to account for both individual properties and emergent properties. In that case, all of the different partitions or subsets must be studied and the selection of any is as good as any other, as long as many different instances are investigated. With any luck, information useful in creating a better and more integrating structure would result.

The specific stimuli, responses, or functional relationships to be researched can be chosen for a variety of reasons:

1. especially revealing
   a. minimal error variance
   b. minimal free parameters
   c. especially general
   d. easy to understand
2. convenient
3. popular
4. under-researched
5. piques curiosity

# II. Structure with Which to Conceptualize Short Time Scale Adaptation

The following figure (11.1) reviews the previously presented molarity by time scale structure (A). Additionally, it presents a contingency by relative imminence of reinforcement by concurrency structure thought to characterize all short time scale adaptation (B). This structure will be developed in the present chapter. Next it provides a linear schematic of how significant events result in a correlation among events in the environment and produce a controlling relationship (C). It then presents the cubic structure which is the unified characterization of the three dimensions which are the elements of learning (D). Finally it provides a scatter plot representation of the four necessary determinants of Thorndikian and Pavlovian conditioning (E).

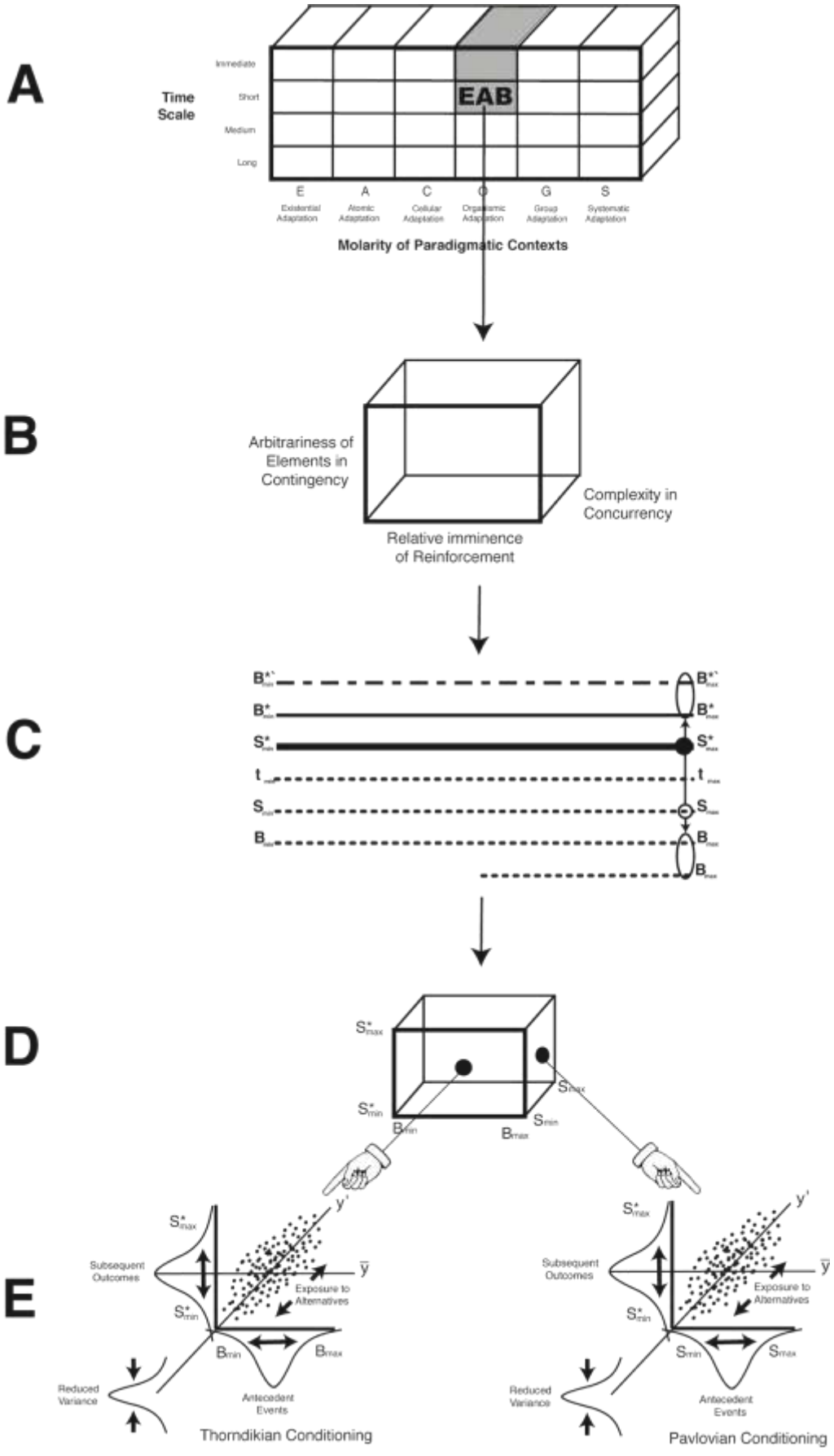

A
Time Scale
Immediate
Short
Medium
Long
EAB
E
A
C
O
G
S
Existential Adaptation
Atomic Adaptation
Cellular Adaptation
Organismic Adaptation
Group Adaptation
Systematic Adaptation
Molarity of Paradigmatic Contexts
B
Arbitrariness of Elements in Contingency
Complexity in Concurrency
Relative imminence of Reinforcement
C
D
E
Subsequent Outcomes
Exposure to Alternatives
Reduced Variance
Antecedent Events
Thorndikian Conditioning
Pavlovian Conditioning

*Figure 11.1 A figure displaying EAB with respect to level of molarity and time scale of adaptation (A); an organizational structure for important dimensions of short time scale adaptation (B); cube representing the relationship between antecedent events and subsequent outcomes (C); and two scatter plots representing conjunctions of events causing learning (D).*

### A. Molarity by Time Scale Structure for Science

The upper portion (A) of Figure 11.1 depicts how psychology (behavior analysis) fits within the levels of molarity of the various sciences and how EAB fits within the time scales of the various areas of psychology. The level of molarity more internal than behavior analysis is cellular adaptation or biology, while the level of molarity above behavior analysis is group adaptation or sociology.

The time scale of adaptation faster than EAB is immediate-time scale adaptation or sensation and perception. Those adaptations are the immediate term expression of some behavior to a stimulus and can have been established across any other time scale. The time scale longer than EAB is medium-time scale adaptation and tends not to reverse in the lifetime of the organism and is thought to require experience with multiple overlapping contingencies. The time scale of adaptation that is even longer than medium time scale is long time scale adaptation and occurs across generations as the result of reproductive success.

### B. Arbitrariness of Elements, by Relative Imminence of Reinforcement, by Complexity of Concurrency Structure for Short Time Scale Adaptation

#### 1. Overview of Structure

The various procedures examining short time scale behavioral adaptation could be organized in terms of the three dimensions illustrated in Section B of Figure 11.1 reproduced below as Figure 11.2. Note that these axes refer to the classes of contingencies of reinforcement involved in short time scale adaptation. It is not the only structure possible, but it is a structure that may capture the most important classes of functional relationships in EAB. The precise nature of each axis is an empirical question.

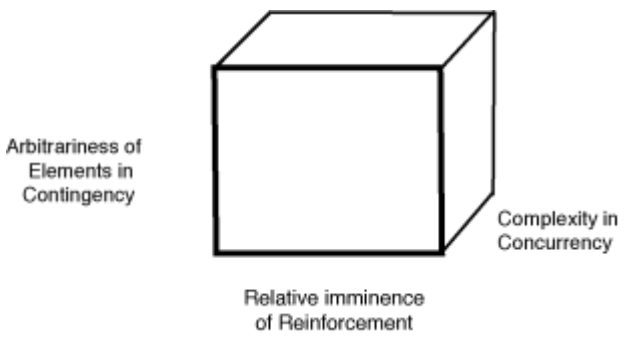


*Figure 11.2 A structure for organizing functional relationships pertaining to short time scale adaptation. Any particular relationship can be characterized by its position on the "Arbitrariness of Elements in Contingency," "Relative Imminence of Reinforcement," and "Complexity in Concurrency" axes.*

The present conceptual structure for short time scale behavioral adaptation organizes various relationships as a function of: 1) degree of arbitrariness of the elements in the contingency, 2) relative imminence of reinforcement, and 3) degree of complexity in concurrency. In sum, any specific behavioral equilibrium could be seen in terms of these three classes of environmental determinants. Alternatively, the positions on the structure could be used to predict the characteristics of the results of a procedure. The predictive accuracy of the structure is an empirical question.

## 2. Axis 1: Arbitrariness of Elements in the Contingency Dimension

The vertical axis of the short time scale adaptation structure in segment B of Figure 11.1 is redrawn as Figure 11.3 in order to specify the proportion flexibility versus proportion inflexibility of the elements in the functional relationship. That is to say, the degree to which the elements in the contingency are arbitrary. This axis is thought to vary from arbitrary stimuli gaining control over an evolutionarily-established behavior (e.g., conditioned reflex) - at the bottom of the structure; to functional relationships between sets of arbitrary stimuli and sets of arbitrary responses established by any of a variety of arbitrary stimuli functioning as reinforcers (e.g., language) at the top of the structure. The order of this axis is an estimate. Its final instantiation awaits empirical data.

A genetically determined functional relationship between causal stimuli and resulting behavior (e.g., any innate behavior such as a reflex) could be said to be totally inflexible, or "phylogenically acquired." It is not represented in the short time scale adaptation structure because it is not the result of short time scale adaptation. It does not emerge across the life span of an individual. This innate functional relationship would be the layer below the bottom layer of Figure 11.3. In the case of an innate behavior, both the stimulus and the response in the functional relationship are said to be fixed rather than arbitrary. The releasing stimulus virtually always elicits the innate response, and the innate response often occurs only to the eliciting or releasing stimulus.

Most presentations of the body of knowledge of short time scale adaptation use what is in effect arbitrariness of elements in a contingency as their primary categorization. This text will do likewise. Each major level will be covered as a chapter. The other two axes "relative imminence of reinforcement" which is most typically instantiated as "position in the interreinforcer interval"(but is also occasionally explicitly controlled) and "complexity in concurrent determination" will be covered within each of those chapters.

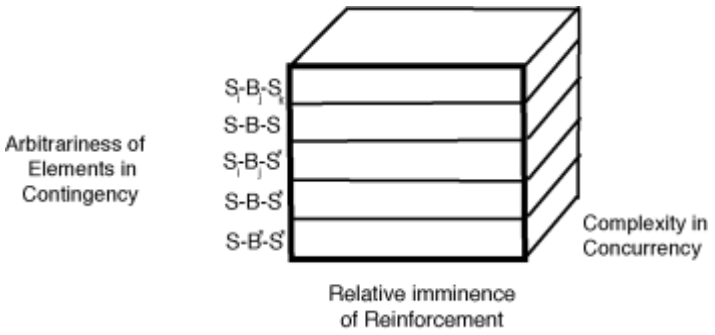



*Figure 11.3 The "Arbitrariness of Elements in Contingency" axis of the organization structure for short time scale adaptation is depicted on the y-axis..*

### a. Functional Relationships Between Arbitrary Stimuli and Fixed Responses as the Result of Fixed Reinforcers (Pavlovian Conditioning) [S-B*-S*]

A conditioned reflex is an example of a functional relationship that shows control over a phylogenically acquired fixed behavior by an arbitrary stimulus and shows short time scale hysteresis (rather than a fixed stimulus unconditionally or always controlling its fixed response as would occur in a reflex). More specifically stated, it is the acquired control over the $B^*_{min}$ - $B^*_{max}$ and or the $B^{*'}_{min}$ $B^{*'}_{max}$ gradient by the $S_{min}$ - $S_{max}$ ($_{or}$ $t_{min}$ - $t_{max}$)gradient as the result of the correlation between the $S_{min}$ - $S_{max}$ and $S^*_{min}$ - $S^*_{max}$ gradient.

This type of short time scale adaptation is represented in the lowest layer of Figure 11.3. This new control is established through ontogenic experience. For example, repeated presentations of a bell that is correlated with food presentation would come to semi-permanently control the salivation previously controlled by food presentation.

### b. Functional Relationships Between Arbitrary Stimuli and Arbitrary Responses as the Result of Fixed Reinforcers (Thorndikian Conditioning) [S-B-S*]

The next layer up in the cube depicted in Figure 11.3 would be exemplified by an operantly conditioned response such as a key peck that is acquired through an individual's repeated exposure to environmental correlations involving both arbitrary stimuli (cues), arbitrary responses (operants), and biologically significant (or fixed) outcomes (primary reinforcers). More specifically stated, it is the acquired control over the $B_{min}$ - $B_{max}$ gradient by the $S_{min}$ - $S_{max}$ or ( $t_{min}$ - $t_{max}$) gradient as the result of the correlation between the $S_{min}$ - $S_{max}$ and $B_{min}$ - $B_{max}$ gradients and the $S^*_{min}$ - $S^*_{max}$ gradient. For example, a key peck to a green key, that is correlated with food presentation will come to occur to the presence of that green key and would show short time scale hysteresis.

### c. Functional Relationships Between Sets of Arbitrary Stimuli and Sets of Arbitrary Responses as the Result of Fixed Reinforcers (Equivalence Relations) [$S_i$ - $B_j$ S*]

The next higher layer in the arbitrariness of elements structure illustrated in Figure 11.3 represents an acquired functional relationship that is even more flexible than a conditioned operant and is labeled equivalence relations. The reinforcer establishes a relationship between any of an arbitrary set of behaviors and any of an arbitrary set of stimuli.

### d. Functional Relationships Between Arbitrary Stimuli and Arbitrary Responses as the Result of Arbitrary Reinforcers (Conditioned Reinforcement and Higher-Order Conditioning) [S-B-S]

The fourth layer of the structure shown in Figure 11.3 is a fixed or an arbitrary response being conditioned to an arbitrary stimulus as the result of that conjunction being correlated with an ontogenically acquired or conditioned reinforcer.

### e. Functional Relationships Between Sets of Arbitrary Stimuli and Sets of Arbitrary Responses as the Result of Sets of Arbitrary Reinforcers (e.g., Language) [$S_i$ - $B_j$ $S_k$]

The top layer in the arbitrariness of elements structure shown in Figure 11.3 depicts sets of arbitrary stimuli coming to control sets of arbitrary responses as the result of a contingency with any of a set of arbitrary or conditioned reinforcers. One example of this level of adaptation is labeled a language, if at least two individuals have had exposure to the same sets of contingencies and their thus acquired behavior functions as controlling and reinforcing stimuli for the other individual in the language community.

## 3. Axis 2: Relative Imminence of Reinforcement Dimension

The second axis of the structure in segment B of Figure 11.1 is redrawn in Figure 11.4. It is the imminence of reinforcement gradient. It is essential to note that this dimension, like reinforcement, requires repeated exposure to its stimuli and their associated imminence to have an acquired effect. This gradient is typically a property of the interreinforcer interval in concatenated trials procedures. While the growing imminence of reinforcement across a fixed interval schedule is immediately apparent and easy to describe, there are procedures other than the passage of time which provide changes in the imminence of reinforcement. A schedule which provides ten distinct stimuli each with a higher probability of, or delay to, food presentation provides an imminence of reinforcement gradient even if randomly presented. A variety of procedures could directly or indirectly change the imminence of reinforcement.

This class of contingencies has a behavioral effect. The behavior could be consummatory just before food presentation in a fixed-interval schedule but fleeing or stalking early in the interval. That is to say, The behavior could be "positive" the moment before reinforcement (i.e., $S^*_{max}$) but "negative" at some other portion of the schedule of reinforcement, such as at the beginning of the interreinforcer interval (i.e., $S^*_{min}$). This axis corresponds with the *x*-axis in the lower left frame of 9.15, 9.18 10.3; the lower x axis in figure 10.2, 10.4, 10.5, 10.6; the vertical axis in figure 10.16; the z axis in figure 10.17; and the x axis in 9.21 10.13,10.19, 10.20, and 10.21. This dimension may be important in the global effect of a complex schedule of reinforcement interacting with local contingencies.

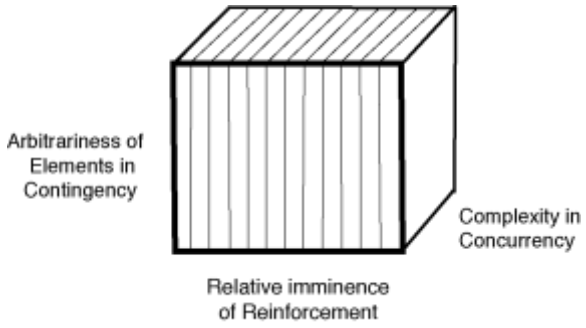



*Figure 11.4 The "Relative Imminence of Reinforcement" axis of the organizational structure for short time scale adaptation is depicted on the x-axis.*

### 4. Axis 3: Complexity in Concurrency Dimension

The third axis of the structure in segment B of Figure 11.1 is redrawn as Figure 11.5. It is the degree to which multiple competing behaviors are being reinforced by the contingencies, or the degree to which multiple behaviors are simultaneously controlled by independent simultaneous contingencies. This dimension goes from none or a single schedule controlling a single behavior (e.g., a simple one key VI schedule) in the front of the structure, to many behaviors simultaneously controlled by many different complex simultaneous contingencies in the back of the structure.

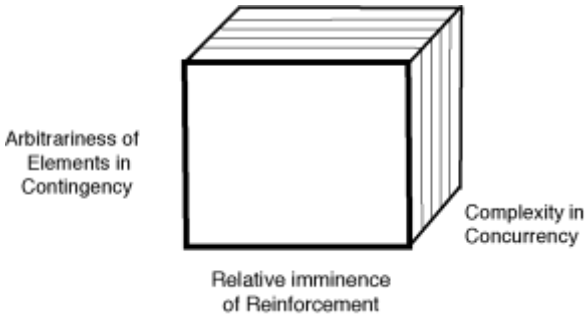



*Figure 11.5 The "Complexity in Concurrency" axis of the organizational structure for short time scale adaptation is depicted across the axis.*

a. Single Contingency (No Concurrency)

b. Simple Concurrent Schedule

c. Dynamic Concurrent Schedule

d. Dynamic Concurrent Schedule with Shift Cost

e. N Alternative Concurrent Schedule

f. Concurrent Chains Schedule

Cautionary follow-up: The ordering of this dimension is speculative

### C. Linear Schema for Dimensions Involved in Short Time Scale Adaptation

The schema shown in segment C of Figure 11.1 and presented as figure 11.6 below illustrates how the $S^*_{min}$ - $S^*_{max}$ gradient elicits or extracts component behaviors and establishes stimulus control over those behaviors when other dimensions are correlated with the $S^*_{min}$ - $S^*_{max}$ gradient.

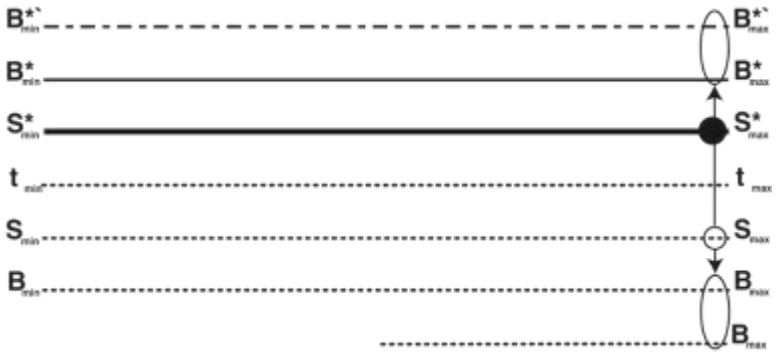


*Figure 11.6 A linear representation of the gradients pertaining to short time scale adaptation such that the various gradients involved are correlated (i.e., the elements portrayed along each gradient are the ones that always occurs in the same position with respect to the elements along the the* $S^*_{min}$ - $S^*_{max}$ *gradient). The heavy line depicts the* $S^*_{min}$ - $S^*_{max}$ *gradient.*

### D. Unified Graphic for Dimensions Resulting in Short Time scale Adaptation

Segment D of Figure 11.1 portrays the dimensions of the causal factors determining short time scale adaptation and its resulting data. It is redrawn as Figure 11.7.in a labeled format to emphasize the requisite relationship between cues, behavior, and subsequent outcomes. In sum, a correlation in antecedent events and functionally significant outcomes ($S_{min}$ - $S_{max}$ X $S^*_{min}$ - $S^*_{max}$ ) or ($B_{min}$ - $B_{max}$ X $S^*_{min}$ - $S^*_{max}$) results in short time scale adaptation: i.e. control of ($S_{min}$ - $S_{max}$ over $B^x_{min}$ - $B^x_{max}$)

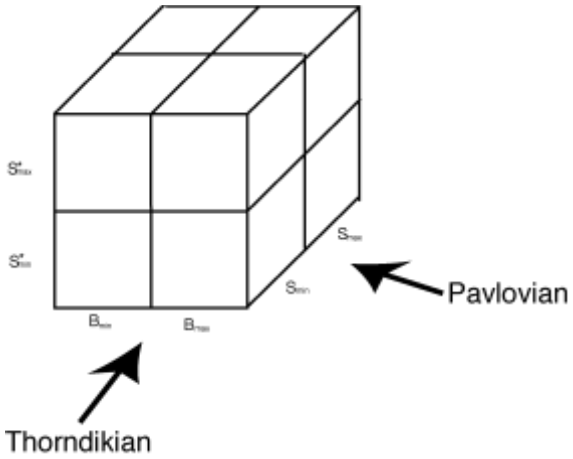



Figure 11.7 The elements necessary for Thorndikian and Pavlovian conditioning set into a 2 x 2 x 2 contingency cube.

**E. Requisite Elements Necessary for Short Time Scale Adaptation**

The two figures in segment E of Figure 11.1 represent the conjunctions of behavior and reinforcers in the left frame, and the conjunctions of stimuli and reinforcers in the right frame which are necessary for short time scale adaptation. The four requisite elements in each case are labeled.

1. **Requisite Elements Necessary for Thorndikian Adaptation**
   a. **Discriminably Different Antecedent Events (Behaviors)**
   b. **Functionally Different Subsequent Outcomes**
   c. **Variance in the Behavior Around y′ less than around y**
   d. **Sufficient Exposure to Alternatives**
2. **Requisite Elements Necessary for Pavlovian Adaptation**
   a. **Discriminably Different Antecedent Events (Stimuli)**
   b. **Functionally Different Subsequent Outcomes**
   c. **Variance in the Behavior Around y′ less than around y**
   d. **Sufficient Exposure to Alternatives**

# III. Conceptual Reflection: Structure For Conceptualizing Short Time Scale Adaptation

The hierarchical relationship of these five organizational schemes (i.e., A, B, C, D, and E) is illustrated in the frames of the conceptual context structure figure given above (Figure 11.1). Taken together, they provided: 1) the context for short time scale adaptation (upper frame "A"), 2) the dimensions of short time scale adaptation (frame "B"), and 3) the cause of short time scale adaptation (lower frames "C", "D", and E).

Models of the natural world are always suspended between the number of dimensions that can be easily envisioned and manipulated (typically three or less at a time) and the number of dimensions that correctly characterize the world. The hope is, that if in reality more than three are required, at least three are sufficient to reduce complexity by a meaningful amount and that nature can be productively conceptualized in dimensions taken three or less at a time because three dimensions are easy to visually portray and understand.

The conceptualization in the present text allows nine orthogonal dimensions to be conceptualized even if it is in groupings of two (time and molarity "A"), and three (arbitrariness of elements in contingency, position in the interreinforcer interval, and complexity in concurrency "B"), and finally the four essential requisites for short time scale adaptation to occur (difference in the antecedent, difference in the consequence, degree of variance reduction or correlation, and degree of exposure to the conjunctions in C, D, and E.

# CHAPTER 12

# The Emergence or Expression of Functional Relationships Between Arbitrary Stimuli and Fixed Responses: "Pavlovian Conditioning"

## I. Introduction

A. Conceptual framework review: the objective of radical behaviorism: demonstrating the externalistic functional relationships that are the cause of behavioral adaptation

## II. Review: Procedures Resulting in an Arbitrary Stimulus Coming to Control a Fixed Response

A. Pavlovian conditioning procedure as a correlation
B. Schematic of Pavlovian conditioning procedure and results
   1. Traditional conceptualization
   2. Bipolar conceptualization of the procedure and results of Pavlovian conditioning
C. Specific instantiations of Pavlovian conditioning
   1. A simplistic trial-by-trial example of Pavlovian conditioning
   2. A more complete phase-by-phase example of Pavlovian conditioning
D. Direct and indirect assessment of Pavlovian conditioning
   1. Documenting the emergence or acquisition of Pavlovian conditioning: a semi-permanent change in behavior as a function of experience with a Pavlovian contingency
   2. Comparing the expressions of Pavlovian conditioning: difference in asymptotic behavior as a function of difference in Pavlovian contingencies

## III. Conceptual Precursor: Terminology Applicable to Pavlovian Conditioning

## IV. Factors Involved in Pavlovian Conditioning

A. Elements involved in Pavlovian Conditioning

1. Subsequent outcome ($S^*_{max}$) ($S^*_{min}$ - $S^*_{max}$)
   a. Origin of the functional significance of the subsequent outcome
      i. Phylogenic
      ii. Ontogenic
   b. Vector or direction controlled by the subsequent outcome
      i. Appetitive
      ii. Aversive
   c. Manifestation of the subsequent outcome
      i. Presentation
      ii. Removal
2. Fixed behavior ($B^*_{max}$) ($B^*_{min}$ - $B^*_{max}$) and ($B^{*'}_{min}$ - $B^{*'}_{max}$)
   a. Level at which the behavior is measured
      i. External
      ii. Internal
   b. Functional properties of the fixed behavior as a function of the relative imminence of $S^*_{max}$
   c. Functional properties of the fixed behavior as a function of the complexity of its concurrent determination
   d. Conceptual context: explanation for discrepancy between CR and UR
      i. Completeness of controlling stimuli
      ii. Phase of the reaction or B* versus B*'
3. Arbitrary stimuli, including time ($S_{max}$)($t_{max}$) ($S_{min}$ - $S_{max}$) and ($t_{min}$ - $t_{max}$)
   a. Source of the arbitrary stimulus
      i. External
      ii. Internal
      iii. Time
   b. Manifestation of the arbitrary stimulus
      i. Presentation
      ii. Removal
4. Arbitrary behavior ($B_{min}$ - $B_{max}$) and ($B_{max}$)

## V. Procedures That Eventuate in Pavlovian Conditioning, or "Schedules of Pavlovian Reinforcement"

A. Conceptual precursor: the preeminence of the events at the moment of the subsequent outcome, reinforcement, or $S^*_{max}$
B. Conceptualizations of families of $S_{max}$ $S^*_{max}$ correlations or contingencies
C. Procedures or schedules of Pavlovian reinforcement to control the specific correlation between $S_{max}$ $S^*_{max}$
   1. Strict simultaneous
   2. Short delay
   3. Long delay
   4. Trace
   5. Backward
   6. Compound

7. Serial
8. Clock
9. Temporal
10. Higher-order
11. Blocking
12. Inhibition

# CHAPTER 12

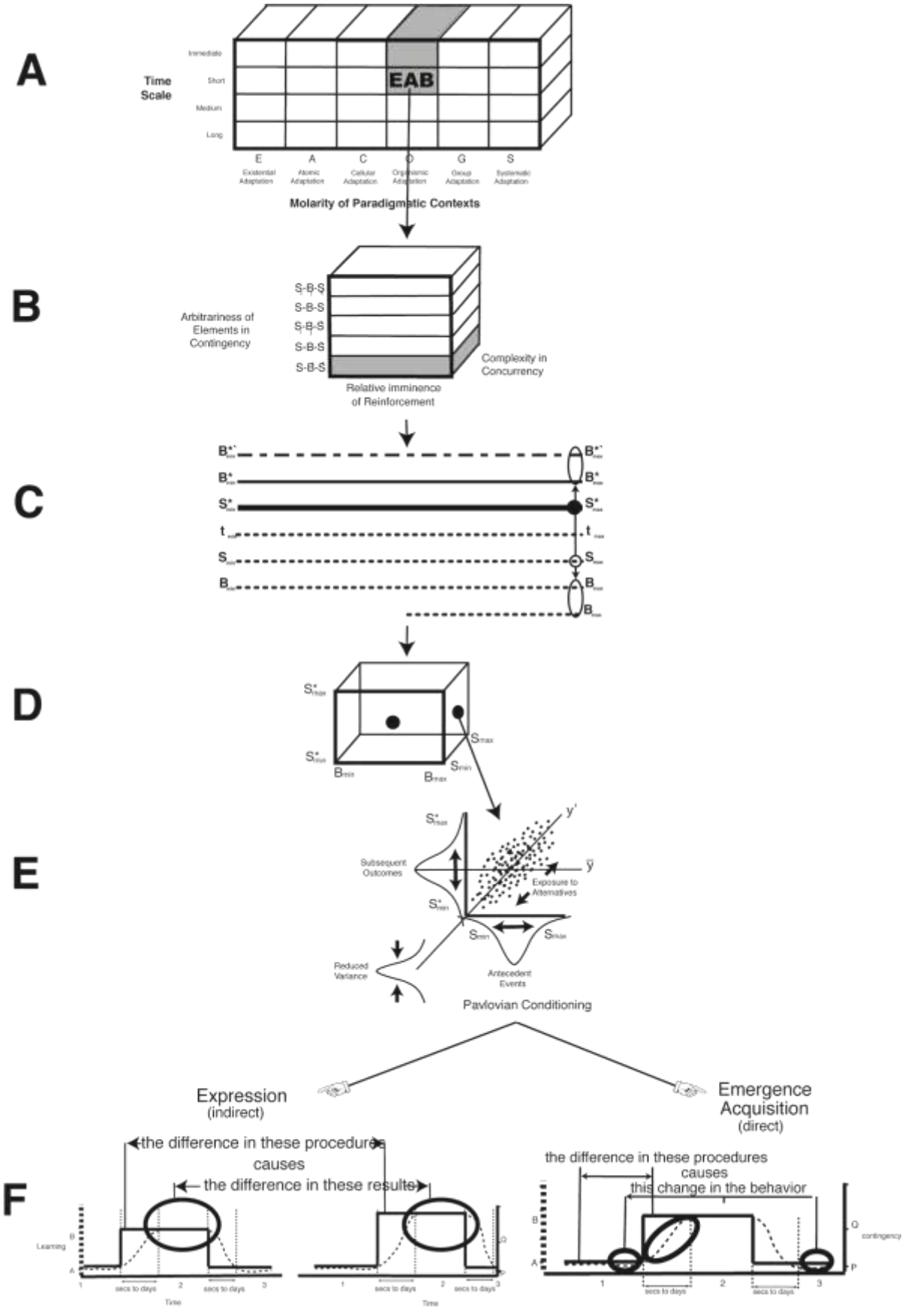
# The Emergence or Expression of Functional Relationships Between Arbitrary Stimuli and Fixed Responses: "Pavlovian Conditioning"

Following chapters 12 and 13 you will present to the class on a research topic in either Pavlovian or Thorndikian conditioning, and field questions from the class. Chapters 12 an 13 provide a framework, terminology, and a review for that task. Present a small set of papers (enough to make a point) as if at ABA. You may presume that your audience is familiar with the material in all the chapters of this text. Choose which journal articles you will present, but be sure to have your choices approved so that only one person will be doing that narrow topic. Start now so you will have plenty of time to prepare

## I. Introduction

In this chapter, we will examine one class of short time scale adaptation. In this class of adaptation an arbitrary stimulus comes to semi-permanently control behavior that had previously been part of a stimulus response functional relationship established by evolution (e.g., reflexes, taxes, modal action pattern, etc.). The process of establishing the new control has been labeled classical conditioning, respondent conditioning, reflex conditioning, and Pavlovian conditioning.

Figure 12.1 illustrates the context of short time scale adaptation (A), the various classes of short time scale adaptation depicted as layers of a cube with the class of adaptation covered in the present chapter highlighted with gray (B); the correlation that causes Pavlovian conditioning is represented in section C, D, and E; finally a direct and indirect way to assess short time scale adaptation is shown in Section F.


A
Time Scale
Immediate
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Existential Adaptation
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Cellular Adaptation
Organismic Adaptation
Group Adaptation
Systematic Adaptation
Molarity of Paradigmatic Contexts
B
Arbitrariness of Elements in Contingency
Complexity in Concurrency
Relative imminence of Reinforcement
C
D
E
Subsequent Outcomes
Exposure to Alternatives
Reduced Variance
Antecedent Events
Pavlovian Conditioning
Expression
(indirect)
Emergence
Acquisition
(direct)
F
the difference in these procedures
causes
the difference in these results
the difference in these procedures
causes
this change in the behavior
Learning
Time
secs to days
contingency

*Figure 12.1 Figure 12.1 illustrates the context of short time scale adaptation (A), the various classes of short time scale adaptation depicted as layers of a cube with the class of adaptation covered in the present chapter highlighted with gray (B); the correlation that causes Pavlovian conditioning is represented in section C, D, and E; finally a direct and indirect way to assess short time scale adaptation is shown in Section F.*

A prior chapter examined innate behaviors. In that chapter, the obtained stimulus-response relationships defining the innate behavior emerged as the result of evolution and were therefore long-term adaptations (a fixed stimulus eliciting a fixed response).

The present chapter also has innate behavior as a central element. However, in this case, we are not interested in the origin of the innate behavior itself or even the simple expression of a response from a functional relationship of evolutionary origin (which would be an immediate-term adaptation). Rather, we proceed to the behavioral adaptation that results in a behavior from a functional relationship of evolutionary origin coming to semi-permanently occur to an arbitrary stimulus as the result of ontogenic experience (i.e., short time scale adaptation). That experience typically entails repeated exposures or "trials" to a correlation between an arbitrary stimulus and a stimulus which elicits or releases a behavior of evolutionary origin.

Simplistically put, in Pavlovian conditioning an arbitrary stimulus comes to elicit or release a fixed response as a result of a reinforcement contingency.

In principle, any innate behavior could be chosen as a dependent variable of Pavlovian conditioning. Tradition has focused on how a reflex can come to be controlled by a new and arbitrary stimulus; but a taxis, or modal action pattern, could equally be the target behavior which comes to be elicited by, or “attached” to an arbitrary stimulus (albeit much more difficult to measure).

In Pavlovian conditioning a phylogenically arbitrary stimulus gradient (i.e., $S_{min}$ - $S_{max}$) comes to control an innate response gradient (i.e., $B^*_{min}$ - $B^*_{max}$ and/or $B^{*'}_{min}$ - $B^{*'}_{max}$) that is normally controlled by an eliciting or releasing stimulus gradient (i.e., $S^*_{min}$ - $S^*_{max}$) where that existing functional relationship is of evolutionary origin. The expression of the behavior in Pavlovian conditioning is basically the same as in the innate behavior and the immediate-time scale adaptation chapter. The emergence of the new functional relationship occurs across the seconds-to-days time scale and is semi-permanent. It is a defining example of short time scale adaptation

Note that in the absence of essential elements from the $S^*_{min}$ - $S^*_{max}$ gradient, the behavior controlled by an element from the $S_{min}$ - $S_{max}$ gradient may differ from that controlled by the $S^*_{min}$ - $S^*_{max}$ gradient. For example, swallowing may not be part of the behavior controlled by an auditory $S_i$ even though $S_i$ was correlated with $S^*_i$, which did control swallowing (i.e. $B^x_i$). In that sense, $B^x_i$ is seen as the result of a reaction chain and its requisite antecedent eliciting stimulus did not occur.

Acquisition and loss of the functional relationship ($S_{a\text{-}h}$ --> $B^x_{a\text{-}h}$) shows short time scale hysteresis. An element in the arbitrary stimulus gradient, $S_d$, is generally presumed to be any stimulus the organism is capable of detecting. In principle It could be a light flash, a bell, a touch, or even internal stimuli such as increased heart rate or blood sugar levels. However, a person may not be able to "consciously" identify either the $S^*_{min}$ - $S^*_{max}$ or $B^*_{min}$ - $B^*_{max}$ of the original reflex or the

occurrence of the $S_{min}$ - $S_{max}$ and $B^*_{min}$ - $B^*_{max}$ of the acquired behavior. For example, the learned functional relationship could, in principle, be entirely internal. In fact, it could be entirely within the liver. However, it is essential to note that it must be a reliable, valid, empirical measure before being given any serious consideration. Speculations are just that: speculations.

A behavior in the fixed response gradient, $B^x$, can be an appetitive or avoidance behavior; foraging or a UR getting response (different stages in a chain leading to consummation;) a compensatory UR to a state displacement; or the rising or falling edge of a UR. Additionally, not all stimuli are necessarily equally likely to become effective CSs in all situations.

### A. Conceptual Framework Review: The Objective of Radical Behaviorism: Demonstrating the Externalistic Functional Relationships that are the Cause of Behavioral Adaptation

A dog exposed to an amber light preceding and correlated with meat powder will come to salivate to the amber light.

Our task is to truly understand why adaptive behavior occurs When the question "why did the dog salivate to the light?" is asked, the answer can take at least two tacks. 1) "Something on the inside made it happen." and, 2) "Something the dog experienced made it happen." Both are true. However, recall the many paragraphs discussing the relative merits of an external functional explanation based on proven facts over an internal tautological conjecture. This issue is so important that radical behaviorism is just as productive if it eliminates consideration of the animal altogether and considers only the prediction of behavior based on environmental events or contingencies. Radical behaviorism is concerned with behavior and what makes it change; it is not at all concerned with the things an animal thinks or any other activities inside the animal. Discussion need not mention the animal unless two different species are being studied, and the difference in the organism is part of the independent variable. The question is what environmental events make the behavior occur, such as pattern, size, and colors in the egg retrieval example (not what does the bird think, how does it process information, or receive space alien signals.)

## II. Review: Procedures Resulting in an Arbitrary Stimulus Coming to Control a Fixed Response

This material is re-presented because it is absolutely essential for you to clearly understand it. **You must totally "see" this "dolphin".** Return to the original extended presentation if it is not perfectly clear after this brief review. Admittedly, this review is too much for some but it is not enough for others. Even if you could have written it yourself on an exam, use the opportunity to confirm or practice your

understanding. A simple way to do that is to pretend that you are teaching a class and have to draw each figure on the board and explain each of the figures in the following review to your class in your own words.

### A. Pavlovian Conditioning Procedure as a Correlation

This material in figure 12.2 was first presented following figure 10.9 and 10.10. Ontogenic experience enables a previously neutral stimulus to semi-permanently control a previously innate response after a relatively few exposures to a correlation between a CS and a US. The origin of this new functional relationship is labeled Pavlovian conditioning.

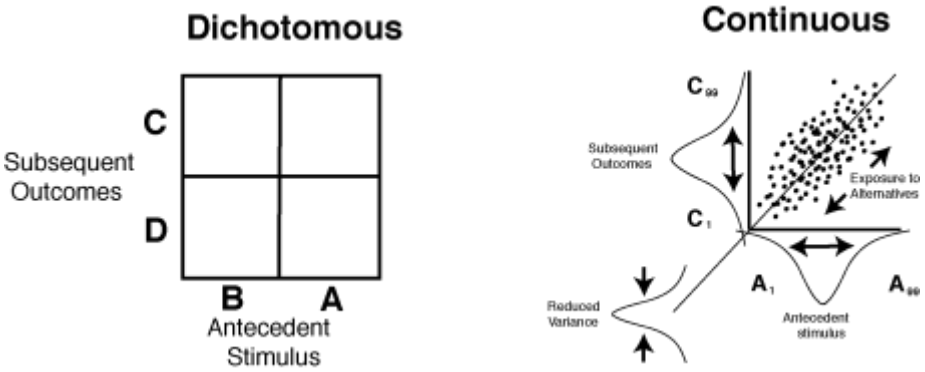



*Figure 12.2 The conjunctions necessary for Pavlovian conditioning depicted in a discrete (left) and continuous (right) format.*

In this case of conditioning, the antecedent events are arbitrary stimuli and the subsequent outcomes are stimuli that elicit an innate behavior.

### B. Schematic of Pavlovian Conditioning Procedure and Results

#### 1. Traditional Conceptualization

This material was first presented following Figure 9.15. Figure 12.3 provides a timing diagram of the traditional conceptualization of a Pavlovian conditioning trial (left frame) and the emergence of the resulting adaptation in the terminal behavior (right frame).

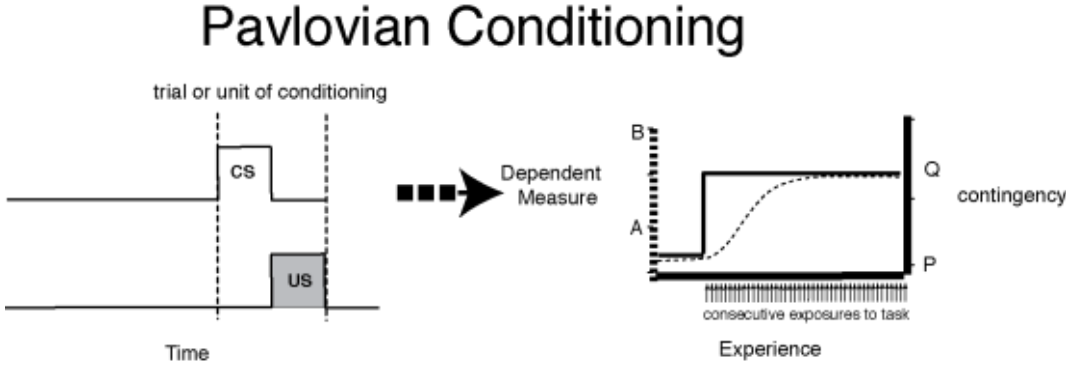


*Figure 12.3 A traditional illustration of Pavlovian conditioning. The left section of the figure depicts a Pavlovian training procedure. A CS is followed by a US. The right portion of the figure illustrates that with many experiences of the Pavlovian contingency or learning task or trial, the dependent measure increases in probability to an asymptotic level. Note that each arrow below the x-axis in the right frame designates the occurrence of a trial containing a CS US pairing.*

As is shown, after an intertrial interval, a CS ($S_{max}$) is presented followed by the US ($S^*_{max}$). As a result, an acquired behavior (a CR) ($B^*_{max}$ or $B^{*'}_{max}$) comes to be elicited by the CS ($S_{max}$) more regularly. As is indicated in the right frame of figure 12.3

### 2. Bipolar Conceptualization of the Procedure and Results of Pavlovian Conditioning

Figure 12.4 provides a depiction of the bipolar correlation conceptualization of a Pavlovian conditioning trial (left frame) and a bipolar version of its obtained results (right frame). In simple term it is a continuous version of the dichotomous version of the procedure and results presented in figure 12.3. The contextual framework for this conceptualization was established following figure 10.12 (left portion of figure 12.4) and following figure 9.21 9.23 and 9.26 (right frame of figure 12.4). Paradigmatically stated: The $S^*_{min}$ - $S^*_{max}$ gradient enables the $S_{min}$ - $S_{max}$ gradient to semi-permanently control the expression of $B^*_{min}$ - $B^*_{max}$ and or the $B^{*'}_{min}$ - $B^{*'}_{max}$ gradient.

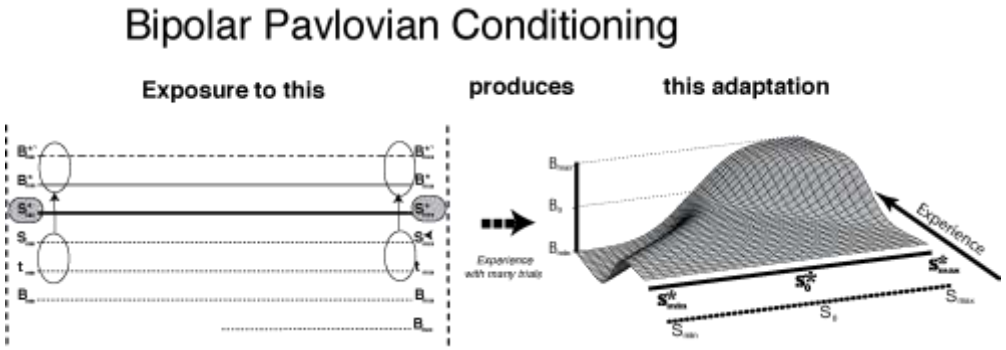



*Figure 12.4 An illustration of Pavlovian conditioning. The left section of the figure illustrates a Pavlovian training procedure. Arbitrary stimuli are correlated with the various portions of an $S^*_{min}$ - $S^*_{max}$ gradient. The right portion of the figure illustrates that with many experiences with that correlation those various stimuli come to control various fixed behaviors.*

In sum, It is a bipolar conceptualization of the conditioning situation and resulting behavioral adaptation.

## C. Specific Instantiations of Pavlovian Conditioning

This material was first presented in Figure 9.12.

### 1. A Simplistic Trial-by-Trial Example of Pavlovian Conditioning

Note that as is indicated on the right edge of the figure, the functional relationship controlled by the amber light was semi-permanently changed by the procedure. What was initially a neutral or "irrelevant" stimulus now reliably and semi-permanently controls a behavior even in the absence of a significant subsequent outcome.

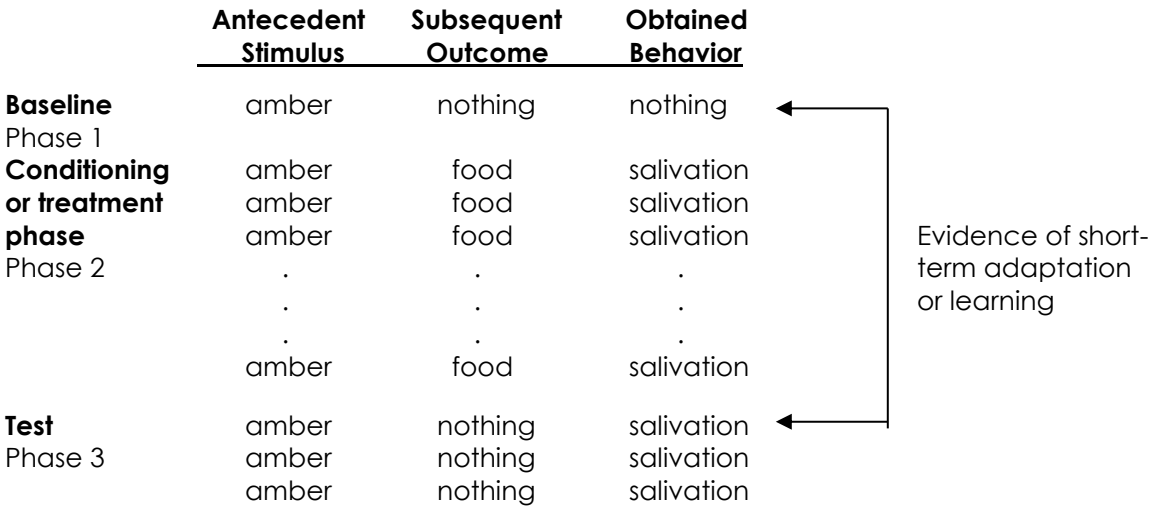



*Figure 12.6 A simplistic illustration that shows that as the result of pairing amber and food presentation, amber by itself comes to elicit salivation. Initially during the baseline (Phase 1), before treatment, the amber light elicits nothing. Following amber food pairings during the conditioning procedure (Phase 2) the presentation of the amber light subsequently controls salivation even when no food follows the light (Phase 3). This test condition is exactly the same as the initial baseline test when amber had not elicited anything.*

It is critical to note that on the first trial of the test phase no food is provided, yet the behavior of salivation occurs anyhow. This is part of the meaning of the "a semi-permanent behavior change." It is the continuance of the high rate of the dependent variable after the contingency is removed in the defining figure for short time scale adaptation given in Figures 1.5 and 9.2.

### 2. A More Complete Phase-by-Phase Example of Pavlovian Conditioning

Figure 12.7 is a re-presentation of Figure 9.13. Note that as is indicated on the right edge of the figure, the functional relation controlled by the amber light has semi-permanently changed. What was initially a neutral or "irrelevant" stimulus in Phase 1 now reliably and semi-permanently controls a behavior in the initial portion of Phase 3.

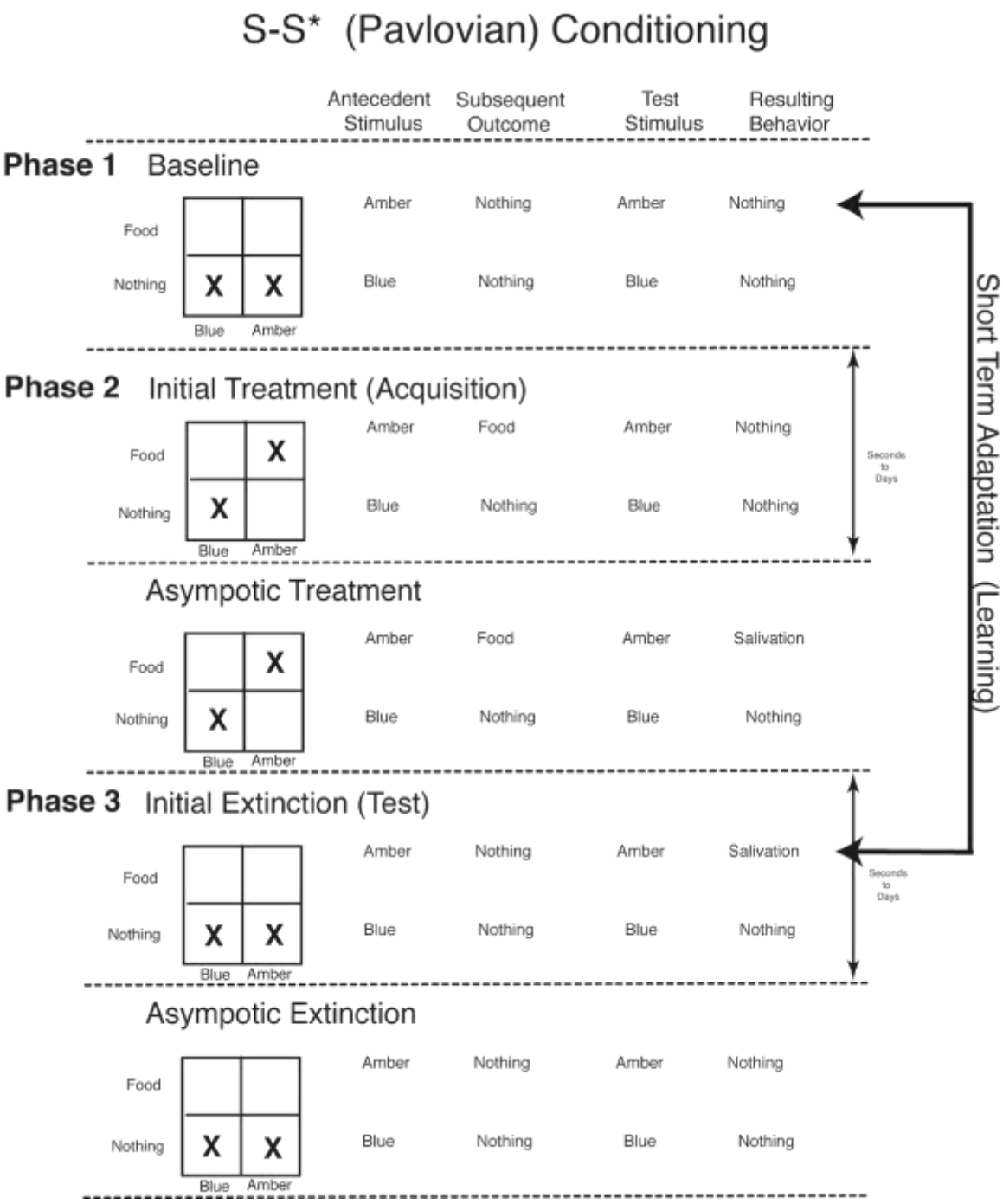



*Figure 12.7 An illustration of a specific instantiation of Pavlovian conditioning. The left portion of each row depicts the procedure to which the animal is exposed as a 2x2 contingency table. The next two columns provide the antecedent stimulus and the subsequent outcomes specified in the contingency table. The fourth column provides the test stimulus and the fifth column provides the resulting behavior to the test stimulus. The top or fifth row (labeled baseline) shows no reaction when the amber stimulus is first presented. Following the treatment in the fourth row (labeled initial treatment) and third (asymptotic treatment) row in which amber preceded food and blue preceded no food, the second row (initial extinction) shows the amber stimulus elicits salivation even when no food is presented. After extended extinction, amber no longer controls salivation as illustrated in the first row.*

## D. Direct and Indirect Assessment of Pavlovian Conditioning

### 1. Documenting the Emergence or Acquisition of Pavlovian Conditioning: A Semi-Permanent Change in Behavior as a Function of Experience with a Pavlovian Contingency

Figure 12.8 shows the emergence of adaption to the conditioning procedures. This material was first presented following Figure 1.18. The expression of a behavior to an arbitrary stimulus (such as a bell) that is being presented immediately preceding the presentation of an $S^*_{max}$ (or US) but not otherwise and is being used as an $S_{max}$ (or CS) in a Pavlovian conditioning paradigm is monitored across repetitive exposure to that stimulus. If a new behavior occurs to the arbitrary stimulus (i.e., the emergence of a new functional relationship) and that functional relationship shows short time scale hysteresis on the onset of the correlation procedure and the removal of that contingency, then that behavior change is an example of short time scale adaptation.

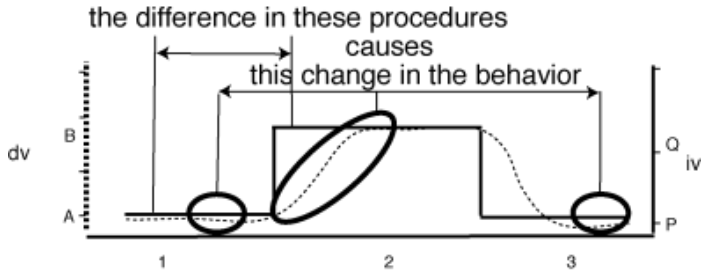



*Figure 12.8 This figure depicts the emergence or acquisition in a dependent variable (dotted line) as a function of a change in the independent variable (solid line). In sum, the change or difference in the dependent measure is caused by the difference in the independent variable. The initial state of behavior or the baseline (in the absence of the treatment) is seen to be recovered at Time 3 when the independent variable is removed.*

### 2. Comparing the Expressions of Pavlovian Conditioning: Difference in Asymptotic Behavior as a Function of Difference in Pavlovian Contingencies

If the asymptotic expression of a behavior to a stimulus (a functional relationship) such as the behavior to a bell that had been used as an $S_{max}$ (or CS) in one specific Pavlovian conditioning paradigm is compared to the expression of the behavior to that bell following asymptotic performance maintained by a different Pavlovian contingency and both of those behavior changes show short time scale hysteresis on both the onset and offset of the Pavlovian contingency then the difference in the functional relationship obtained in the two procedures can be attributed to the difference in the short time scale adaptation caused by those two procedures. This is shown in figure 12.9. This information was first presented in Figure 1.17. The difference in Pavlovian contingency could, for example, be 1 gram versus 10 grams of meat powder used as the US.

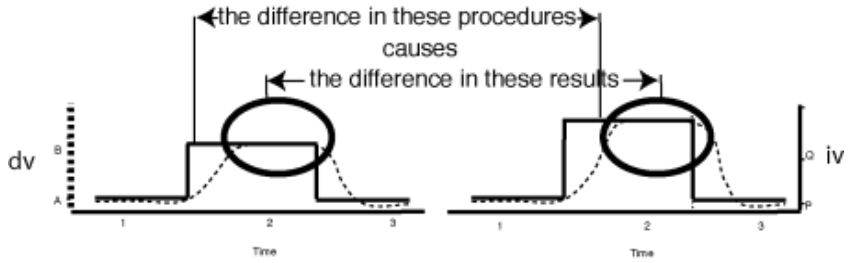



*Figure 12.9 This figure depicts the difference in the asymptotic expression or performance of a dependent variable (dotted line) as a function of a difference in the independent variable (solid line). In sum, the difference in the dependent variable is caused by the difference in the independent variable.*

# III. Conceptual Precursor: Terminology Applicable to Pavlovian Conditioning

**Conditioned / Conditional**

The original translation of Pavlov's work mistranslated the Russian word Pavlov used as "conditioned" rather than translating it as "conditional" as it should have been. Pavlov had said that the CR reaction to the CS was conditional on its pairing with the US. Otherwise, the CS was just a neutral stimulus. The word conditioned has now had such a long history of usage, the tendency has been to keep it even though conditional is a more parsimonious (and radical behavioral) description of the event.

**UCS or US**

A UCS ($S^*_{max}$) is a stimulus that unconditionally always elicits a response labeled a UCR ($B^*_{max}$ or $B^{*'}_{max}$). More correctly stated, it should be written UCS-UCR together as one unit. The UCS virtually never occurs without the resulting UCR. Alternatively stated, a fixed stimulus (UCS) elicits a fixed response (UCR). Exemplars are virtually always from a reflex such as meat powder – salivation but in principle could be from any innate stimulus reaction pair.

- Most comprehensively put, the label would be $S^*_{min}$ - $S^*_{max}$ rather than UCS or US for most repetitive trial procedures. This would provide for all the evolutionarily established functional relationships that are an aspect of the total stimulus-reaction pair.
- The most comparable element to the UCS in the bipolar framework would be $S^*_{max}$.

**UCR**

The UCR ($B^*_{max}$ or $B^{*'}_{max}$) is the innate response elicited by the UCS ($S^*_{max}$). For example, it is not just any salivation that happens to occur, it is salivation caused by the UCS. Salivation is only labeled a UCR if it occurs as a result of the UCS. It is the

fixed response (UCR) elicited by a fixed stimulus (UCS). It is half of the UCS-UCR pair.

- Most comprehensively put, the label would be $B^*_{min}$ - $B^*_{max}$ and $B^{*'}_{min}$ - $B^{*'}_{max}$. This would provide for all the evolutionarily established functional relationships that are an aspect of the stimulus-reaction pair.
- The most comparable element to the UCR in the bipolar framework would be $B^*_{max}$.

**CS**

Most correctly stated, initially the CS ($S_{max}$) should be labeled the "to-be-CS" because initially it is just an arbitrary neutral stimulus with no power to elicit what will be the CR. After training, the to-be-CS becomes the conditioned stimulus by coming to elicit the CR.

- Most comprehensively put, the label would be $S_{min}$ - $S_{max}$.
- The most comparable element to the CS in the bipolar framework would be $S_{max}$.

**CR**

The CR ($B^*_{max}$ or $B^{*'}_{max}$) is the behavior that comes to be elicited by the CS. The CR has some non-arbitrary relationship to the UCR. Additionally, it is not simply any salivation (in the meat powder salivation case), it is salivation elicited by the CS. Additionally, the precise form of $B^*_x$ and $B^{*'}_x$ may be different when elicited by $S_x$ or $t_x$. in that the $B^*_x$ and $B^{*'}_x$ may contain reaction chains that fail to be elicited by elements of the $S_{min}$ - $S_{max}$ and $t_{min}$ - $t_{max}$ gradients. The full relationship between the innate reaction and the conditioned reaction awaits empirical research.

- Most comprehensively put, the CR would have to be labeled $B^*_{min}$ - $B^*_{max}$ and $B^{*'}_{min}$ - $B^{*'}_{max}$ because it could be similar to the UR or similar to the compensatory response. Additionally, it would be necessary to explain any difference between the UR and the CR and when a B* reaction or B*' reaction could be expected.
- The most comparable element to the CR in the bipolar framework would be $B^*_{max}$ and $B^{*'}_{max}$.

**Trial**

Trial refers to a unitary learning experience. It is across this unit that learning with experience is said to take place. Traditionally, it refers to the presentation of the CS and UCS together.

- Most comprehensively put, a trial is the exposure to the $S^*_{min}$ to $S^*_{max}$ interval and any elements that are correlated with that gradient either by design or by accident. (The entire illustration in Figure 10.12).
- The most comparable element to a trial in the bipolar framework would be the exposure to the entire set of gradients illustrated in Figure 10.12.

**Trial Stimulus**

A trial stimulus is a presentation of the CS ($S_{max}$).

- Most comprehensively put, the entire set of stimuli correlated with the $S^*_{min}$ to $S^*_{max}$ gradient would need to be specified which would be the $S_{min}$ - $S_{max}$ and $t_{min}$ - $t_{max}$ gradients.
- The most comparable element to a trial stimulus in the bipolar framework would be $S_{max}$.

**Intertrial Interval (ITI)**

This is the time from the beginning of a learning trial (usually the offset of the preceding UCS in a concatenated trials procedure) to the onset of the trial stimulus.

- The most comparable element to an ITI in the bipolar framework would be the interval from $S^*_{min}$ to $S^*_{max\text{-}x}$

**Interstimulus Interval (ISI)**

Typically, this is the time from the onset of the trial stimulus to the onset of the UCS. However, it could refer to the time between any two stimuli.

- The most comparable element to the ISI in the bipolar framework is the interval from $S_{max\text{-}x}$ to $S^*_{max}$.

**Cycle**

In the typically procedure of concatenated trials, this is the entire time from the end of one reinforcer to the beginning of the next reinforcer (i.e., the ITI plus the duration of the trial time or the intertrial time plus the interstimulus interval time (C = (ITI + ISI))

The most comparable element to the cycle in the bipolar framework is the interval from $S^*_{min}$ to $S^*_{max}$.

**$S^*_{min}$ - $S^*_{max}$ Gradient**

The gradient of "value" from the least imminent to the final subsequent outcome.

**$S_{min}$ - $S_{max}$ Gradient**

The gradient of arbitrary stimuli correlated with portions of the $S^*_{min}$ - $S^*_{max}$ gradient, if there is a systematic relationship between $S_{min}$ - $S_{max}$ and $S^*_{min}$ - $S^*_{max}$.

**$t_{min}$ - $t_{max}$ Gradient**

The gradient of temporal "stimuli" correlated with portions of the $S^*_{min}$ - $S^*_{max}$ gradient, if there is a systematic relationship between $t_{min}$ - $t_{max}$ and $S^*_{min}$ - $S^*_{max}$.

**$B^*_{min}$ - $B^*_{max}$ Gradient**

The gradient of evolutionary established behaviors controlled by portions of the $S^*_{min}$ - $S^*_{max}$ gradient.

**$B^{*'}_{min}$ - $B^{*'}_{max}$ Gradient**

The gradient of behaviors that "compensate for" or go with the $B^*_{min}$ - $B^*_{max}$ gradient. They are typically seen as evolutionary origin but could be of short time scale or medium-term origin. The final understanding awaits empirical resarch.

# IV. Factors Involved in Pavlovian Conditioning

## A. Elements involved in Pavlovian Conditioning

### 1. Subsequent Outcome ($S^*_{max}$) ($S^*_{min}$ - $S^*_{max}$)

Traditionally, this is seen as presenting or not presenting a UCS or a reinforcer (e.g., $S^*_{max}$). Functionally, it is the occurrence of any stimulus that creates the correlational structure illustrated in Figure 10.12. It could be said to be a stimulus with "value," or as Donahoe and Palmer suggest "a stimulus which controls a behavioral adjustment." More completely the subsequent outcome is the second half of the gradient of outcomes or the $S^*_{min}$ - $S^*_{max}$ gradient.

#### a. Origin of the Functional Significance of the Subsequent Outcome

##### i. Phylogenic

These subsequent outcome stimuli are typically labeled an unconditioned or unconditional stimulus. These are stimuli that acquired their effectiveness as the result of evolution. The stimuli are effective in virtually every member of the species.

##### ii. Ontogenic

These subsequent outcome stimuli are typically labeled a higher-order reinforcer. These are stimuli that acquired their effectiveness as the result of the learning history of that particular individual.

#### b. Vector or "Direction" Controlled by the Subsequent Outcome

##### i. Appetitive

These subsequent outcome stimuli control approach behavior. In Thorndike's words, the animal does nothing to avoid, often doing such things to attain and preserve it.

##### ii. Aversive

These subsequent outcome stimuli control avoidance behavior. In Thorndike's words, one which the animal commonly avoids and abandons.

#### c. Manifestation of the Subsequent Outcome

##### i. Presentation

The stimulus occurrence or onset is conceptualized as the subsequent outcome stimulus, or operative event.

##### ii. Removal

The stimulus absence or offset is conceptualized as the subsequent outcome

stimulus or operative event.

### 2. Fixed Behavior ($B^*_{max}$) ($B^*_{min}$ - $B^*_{max}$) and ($B^{*'}_{min}$ - $B^{*'}_{max}$)

These are the behavior gradients controlled innately by the $S^*_{min}$ - $S^*_{max}$ gradient.

#### a. Level at Which the Behavior is Measured

at what level are the measures taken

##### i. External

The measure of the fixed behavior is an activity of the whole organism and is apparent outside the skin of the organism.

##### ii. Internal

The measure of the fixed behavior is an activity of cells or cell assemblies. Note that this refers to empirically measured reactions within the organism.

#### b. Functional Properties of the Fixed Behavior as a Function of the Relative imminence of $S^*_{max}$

#### c. Functional Properties of the Fixed Behavior as a Function of the Complexity of its Concurrent Determination

#### d. Conceptual Context: Explanation for Discrepancy Between CR and UR

##### i. Completeness of Controlling Stimuli

The difference between the UR or the reaction to $S^*_{max}$ and the CR or the reaction to $S_{max}$ is to be seen as the result of the difference in the eliciting properties of the components of $S^*_{max}$ and $S_{max}$. Any behaviors that are latter segments of a reaction chain controlled by stimuli produced by $S^*_{max}$ that are not produced by $S_{max}$ would be expected to be absent from the reaction to $S_{max}$.

##### ii. Phase of the Reaction, or B* versus B*'

In some situations, the discrepancy between the CR and the UR may be the result of different phases of the fixed reaction being predominant. When to expect the fundamental reaction (B*) and when the compensatory reaction (B*') is pending empirical research.

### 3. Arbitrary Stimuli, Including Time ($S_{max}$) ($t_{max}$) ($S_{min}$ - $S_{max}$) and ($t_{min}$ - $t_{max}$)

These are stimuli whose relevance to the conditioning procedure comes from their ontogenic correlation with some aspect of the $S^*_{min}$ - $S^*_{max}$ gradient rather than any phylogenic relationship. In Pavlovian procedures, this is typically the intertrial stimulus and the following trial stimulus or both the negative CS and the positive CS. More completely, this is the entire $S_{min}$ - $S_{max}$ and $t_{min}$ - $t_{max}$ gradient.

#### a. Source of the Arbitrary Stimulus

##### i. External

Prototypically, a neutral stimulus such as a bell.

##### ii. Internal

For example, blood pressure or glucose level. It should go without stating that these stimuli must be empirically verified measures.

##### iii. Time

The source of time and its receptor are unknown. For convenience, it is conceptualized the same way as a tone or light. Often in this text, the temporal gradient is considered just another stimulus gradient in order to simplify exposition. It is reasonable to presume that time is included in any discussion of controlling stimuli.

#### b. Manifestation of the Arbitrary Stimulus

##### i. Presentation

Most typically, the statement "a stimulus occurred" implies that some stimulus was presented.

##### ii. Removal

Occasionally, the removal of a stimulus such as turning off a light serves as "a stimulus."

### 4. Arbitrary Behavior ($B_{min}$ - $B_{max}$) and ($B_{max}$)

In Pavlovian procedures, arbitrary behavior is rarely recorded and is virtually always ignored because it is considered irrelevant. Occasionally, there are anecdotal stories of arbitrary behavior in a Pavlovian conditioning procedure.

# V. Procedures That Eventuate in Pavlovian Conditioning, or "Schedules of Pavlovian Reinforcement"

Pavlovian conditioning occurs as the result of the correlation of antecedent stimuli and subsequent outcomes. The behavior gradients $B^*_{min}$ - $B^*_{max}$ and $B^{*'}_{min}$ - $B^{*'}_{max}$ come to be controlled by the stimulus gradient $S_{min}$ - $S_{max}$ or temporal gradient $t_{min}$ - $t_{max}$ as a result of those respective gradients being correlated with the $S^*_{min}$ - $S^*_{max}$ gradient. The label for the procedure used to create/enforce those correlations is a "schedule of Pavlovian reinforcement," regardless of whether it is artificially instantiated by a researcher or is naturally occurring.

## A. Conceptual Precursor: The Preeminence of the Events at the Moment of the Subsequent Outcome, Reinforcement, or $S^*_{max}$

The specific details of the stimulus ($S_{max}$) that precedes the unconditioned stimulus ($S^*_{max}$) strongly controls the details of the conditioned response ($B^*_{max}$). The Pavlovian research generated by the Experimental Analysis of Behavior, is to document those factors.

Schedules of Pavlovian reinforcement are analytical procedures to assure the conjunction of specific events at the moment of reinforcement, unfortunately however their groupings and labels sometimes reflect the evolution of their conceptualization and subsequent research popularity rather than their functional impact or an overall top down systematic conceptual structure.

It should be noted that schedules of Pavlovian reinforcement were developed as analytical tools with which phenomena could be understood by controlling important causal factors rather than as the instantiation of everyday situations in the laboratory where those everyday situations could be examined more thoroughly.

## B. Conceptualizations of Families of $S_{max}$ $S^*_{max}$ Correlations or Contingencies

At a basic level $S^*_{max}$ could be an appetitive or aversive outcome and the dependent variable could be an external or internal reaction. In addition, the $S^*_{max}$ could be the presentation or the removal of a stimulus. However, Pavlovian conditioning by removing a UCS does not have a substantial database.

All eight of these possibilities are illustrated in Figure 12.10 as a 2 x 2 x 2 contingency table in order to be maximally symmetrical with the analogous categorization of families traditionally applied to Thorndikian contingencies. It is important to note that the internal/external distinction refers to where the empirical measures are obtained not the locus of the explanatory cause of the behavior.

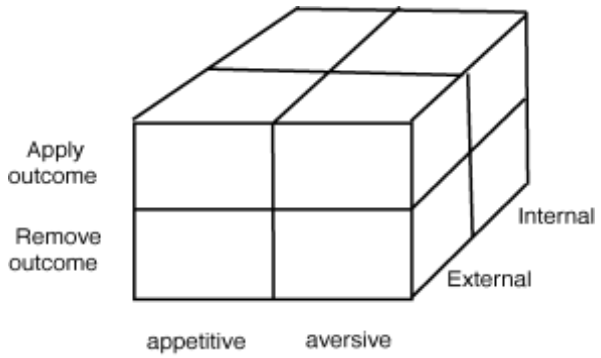



*Figure 12.10 A 2x2x2 contingency table illustrating the combinations of applying or removing an outcome as the result of the occurrence of an antecedent arbitrary stimulus. It is provided as an analog of the traditional terminology for families of contingencies in Thorndikian procedures.*

### C. Procedures or Schedules of Pavlovian Reinforcement to Control the Specific Correlation Between $S_{max}$ and $S^*_{max}$

In the following figures, the procedures are represented as they were when the schedules of Pavlovian reinforcement were first conceptualized and labeled. The events are depicted as ovals and the ovals are superimposed on the bipolar designations. When originally defined, the importance of the ratio of the trial stimulus duration to the overall intertrial interval was poorly understood. Similarly, only the behavior at $S^*_{max}$ was considered. Traditionally, the procedures were thought to contain a period when nothing happened followed by a period when a signal and a functionally significant event was presented. For example, two minutes of silence ($S_{min}$) followed by a bell ($S_{max}$) immediately followed by meat powder ($S^*_{max}$). The behavior or reaction to that procedure was also thought to be dichotomous. For example, a dog quietly standing in a harness ($B^*_{min}$), then profusely salivating ($B^*_{max}$) to a bell ($S_{max}$) just before meat power was placed in the mouth ($S^*_{max}$). That is to say that prior to the trial stimulus was a dead zone where nothing happened and no conditioning of any kind occurred.

Recall the discussion about the contrasting ramifications of a traditional contiguity versus a bipolar correlational perspective presented following Figure 10.19.

View the following figures in the traditional format by focusing on only the oval elements or alternatively see the procedures in terms of their entire context by focusing on the ovals in the context of the elements on an $S_{max}$ - $S^*_{max}$ continuum as portrayed in Figure 10.12 and 12.4.

The oval depicting the UR is stretched to co-occur with the trial stimulus to suggest that the CR was thought to be a function of the UR without necessarily being the same.

### 1. Strict Simultaneous

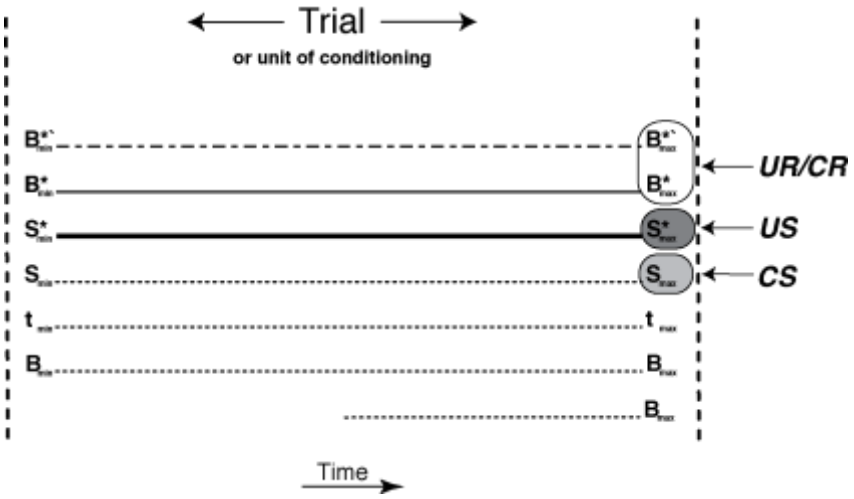



*Figure 12.11 A strict simultaneous trial procedure in which the CS and US are coterminous*

In strict simultaneous conditioning, the CS and the US come on and go off at exactly the same time. Typically, a strictly, simultaneous procedure does not come to control a CR.

Sometimes it does control a CR but at a substantially weaker level than a short delay procedure.

Additionally, the strict simultaneous procedure may control some behavior other than the UR obtained with a short delay procedure.

### 2. Short Delay

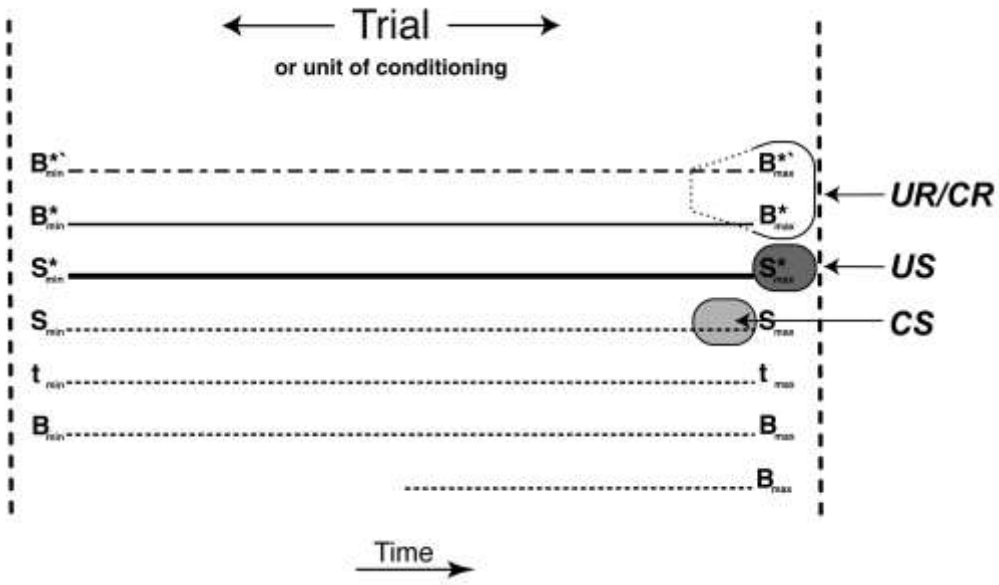



*Figure 12.12 A prototypical short delay trial procedure in which the CS precedes the US. The offset of the CS tends to occur at the same time as the onset of the US but it can terminate after the US onset.*

Typically, in short delay schedules, the inter-stimulus interval (CS to US) is less than 10 seconds in duration but this was determined on intertrial intervals around 2-5 minutes long.

An artifact of the typical running procedure generally made the CS duration short with respect to a much longer intertrial interval.

Typically, this procedure is the most effective at controlling the CR.

The specific behavior being monitored and the cycle duration (time from end of previous reinforcer to onset of current subsequent outcome) strongly affect the ideal duration of the CS. For example, shortening the intertrial interval to about 15 seconds would undercut the effectiveness of a 10-second trial stimulus, while increasing an intertrial interval to about an hour would dramatically increase the effectiveness of a 60-second trial stimulus.

### 3. Long Delay

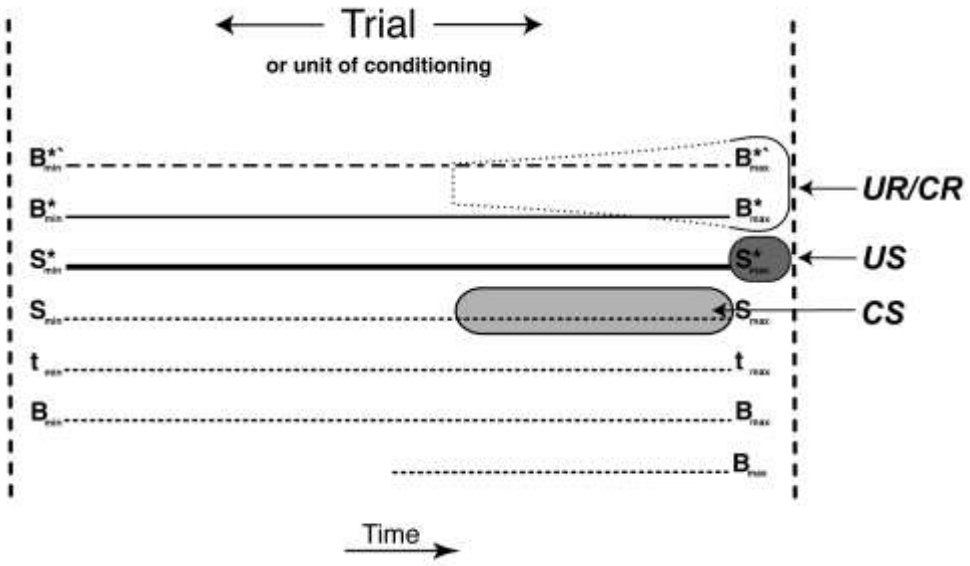



*Figure 12.13 A long delay trial procedure in which the CS precedes the US by a relatively long time. The offset of the CS tends to correspond with the onset of the US but it can terminate after the US onset.*

Typically, in long delay schedules, the inter-stimulus interval (CS to US) is around 60 seconds but this was determined on intertrial intervals that were 2-5 minutes long.

There is typically less conditioning of the CR than with short delay

An artifact of the typical running procedure made the CS duration relatively long with respect to the intertrial interval (e.g., coming on at the approximate midpoint of the interfood interval).

The conditioned response typically starts at the onset of the CS but maximum amplitude is at the approximate time of the US

Suppression of the CR at the beginning of the trial stimulus is labeled inhibition of delay. The present view is that this latter effect is a second order bipolar effect

### 4. Trace

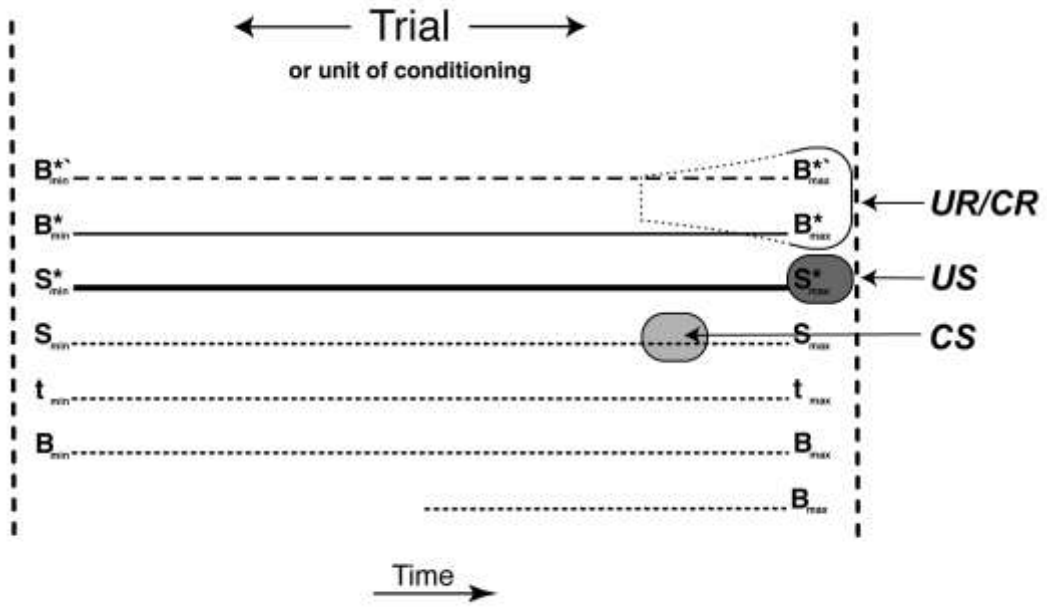



*Figure 12.14 A trace trial procedure in which the CS precedes the US and terminates before the onset of the US. The intervening time is the same stimulus condition as the intertrial interval.*

In the trace conditioning procedure, the CS stimulus comes on and goes off before the US presentation. As a result, the stimulus conditions immediately preceding the US are the same as those at the beginning of the trial.

This procedure is less effective in conditioning a CR than a short delay procedure whose CS onset occurs at the same time as a trace trial stimulus onset. The "hole" (or return to the $S_{min}$ stimulus) undercuts the effectiveness of the trial stimulus.

### 5. Backward

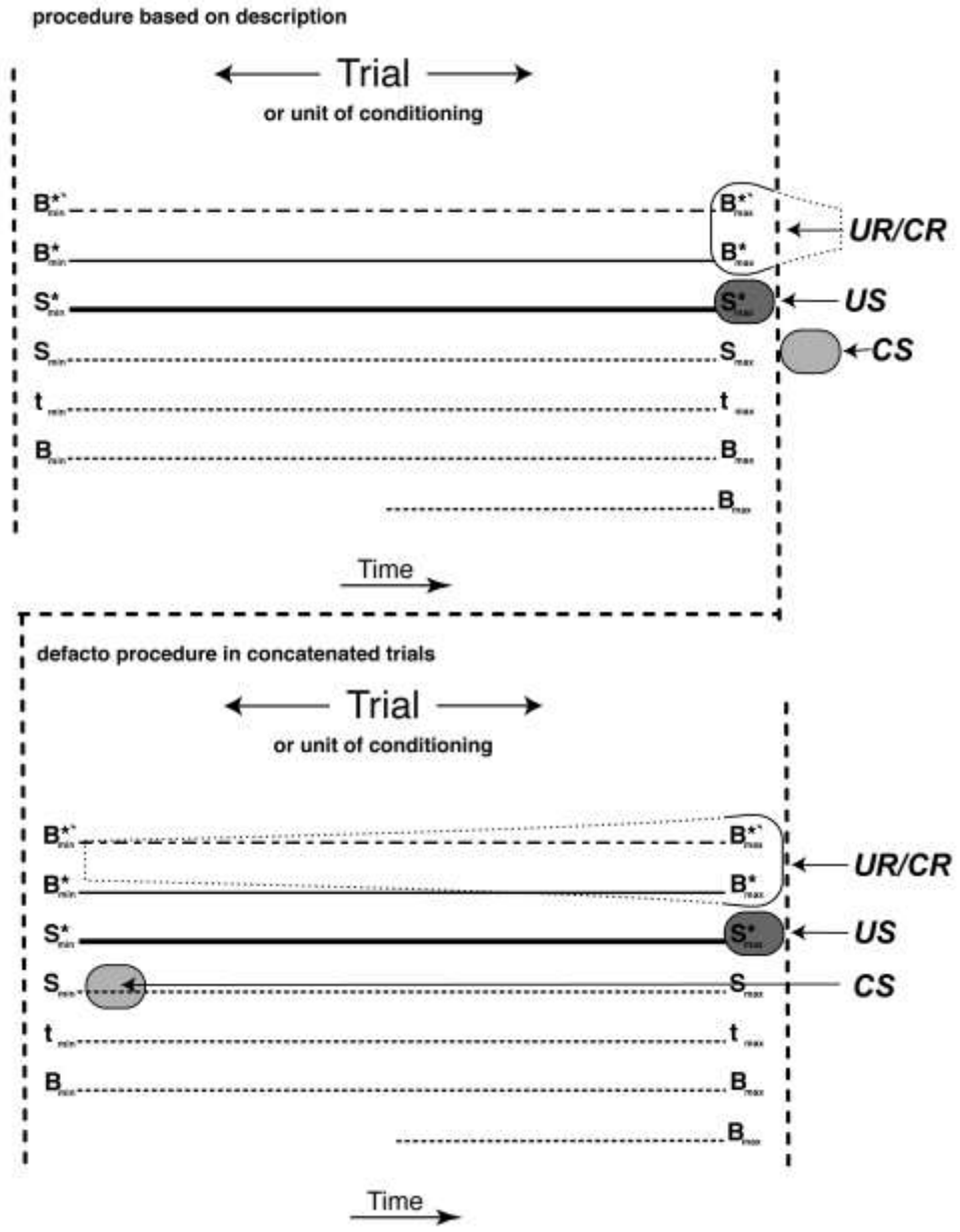



*Figure 12.15 A backward conditioning trial procedure in which the CS occurs immediately following the US. The onset of the CS generally corresponds with the offset of the previous US.*

In backward conditioning procedures, the CS is presented immediately after the US presentation. In a concatenated trials procedure, this is presenting the CS at the beginning of the trial or at $S^*_{min}$. Typically, this procedure does not come to control the CR obtained with short delay conditioning procedures.

Sometimes the procedure does work but is weaker than short delay.

Additionally, this procedure may control some behavior other than the typical CR seen in short delay. From the bipolar perspective $S_{min}$ comes to control $B^*_{min}$ or $B^{*'}_{min}$.

### 6. Compound

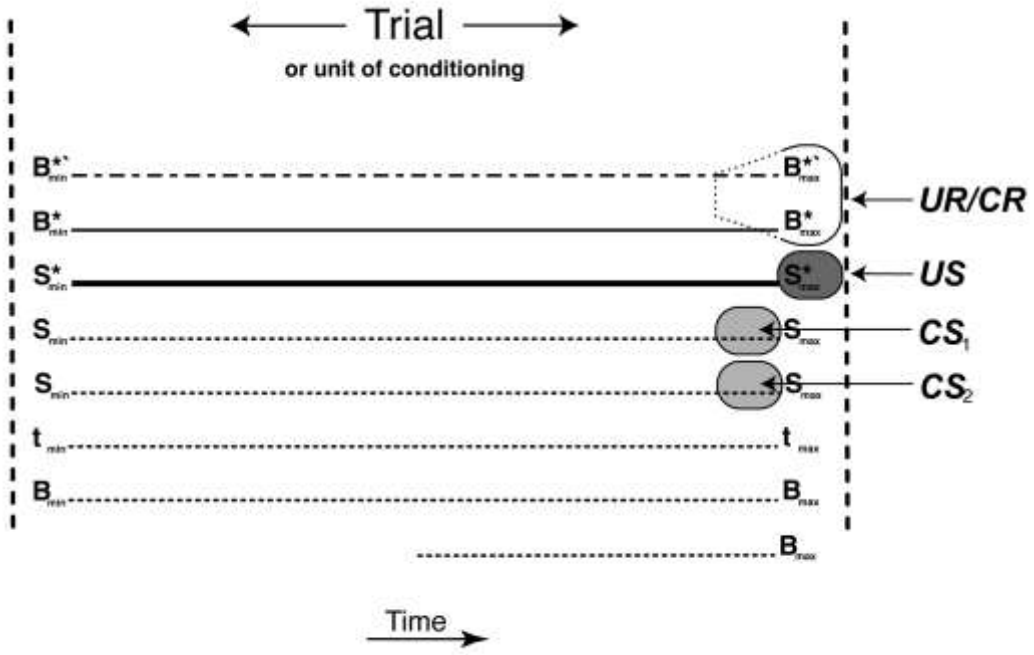



*Figure 12.16 A compound conditioning trial procedure in which two different CSs occur immediately preceding the US. The two stimuli are usually co-terminus. The offset of the two CSs, generally corresponds with the onset of the US.*

In compound conditioning, two different stimuli are presented at the same time immediately before the US presentation.

What is conditioned to each CS is a function of several factors such as relative salience of the two stimuli, and the prior conditioning history of each specific stimulus.

This procedure has been used to good effect to reveal important determinants of Pavlovian conditioning.

This is a Pavlovian implementation of a concurrent schedule.

### 7. Serial

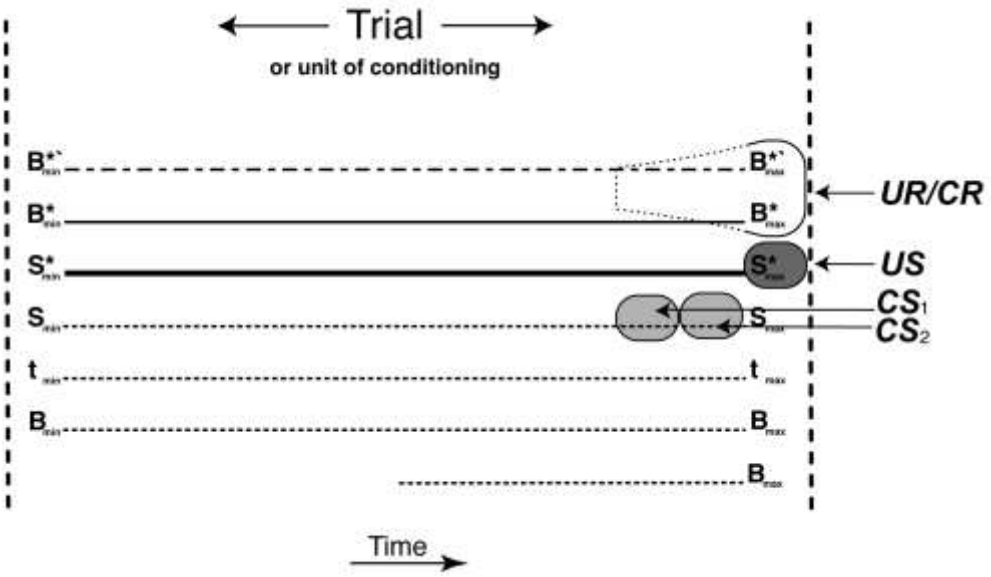



*Figure 12.17 A serial trial procedure in which CS1 occurs and is immediately followed by CS2. The offset of CS2 (or CSn) generally immediately precedes the onset of the US.*

In serial conditioning procedures, a series of different contiguous CS stimuli are presented after an ITI

## 8. Clock

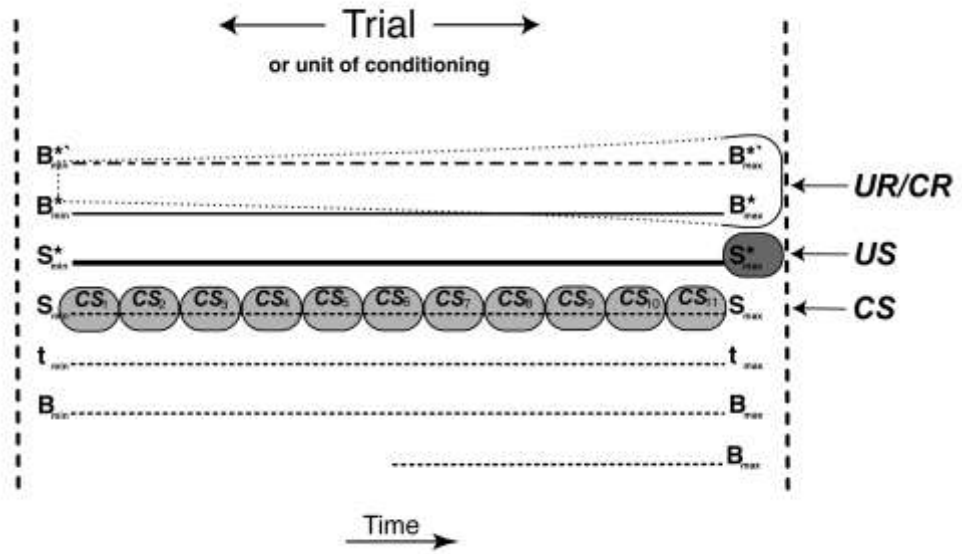



*Figure 12.18 A clock trial procedure is one in which the entire interfood interval is segmented into different discrete stimuli.*

In a clock procedure, a series of discrete explicit CS stimuli across the entire interfood interval are presented. There is no intervening stimulus between the clock stimuli and none preceding the first clock stimulus

This procedure could be labeled a free respondent and has been used to good effect to reveal important determinants of short time scale adaptation.

### 9. Temporal

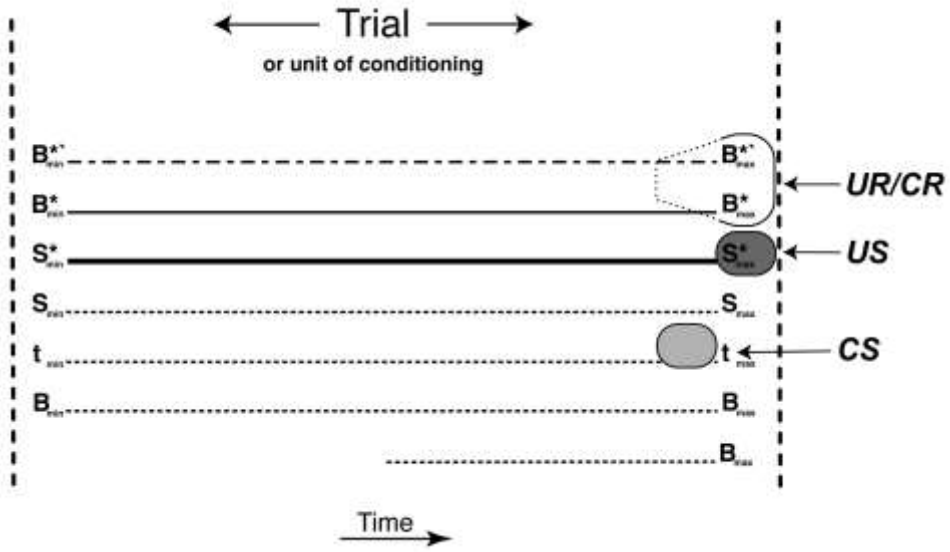



*Figure 12.19 A temporal conditioning trial procedure in which the US is presented at regular intervals but no explicit CS is presented. It is presumed that temporal stimuli function as the CS.*

In a temporal conditioning procedure, no explicit CS stimulus is presented, only the passage of the same time since some marker such as the trial start is correlated with the subsequent outcome. For example, the US could always be presented 60 seconds after the offset of the prior US in a fixed trial duration procedure. Clearly, the CS in this procedure is a temporal stimulus. In principle, there could be a variable time Pavlovian procedure.

## 10. Higher-order

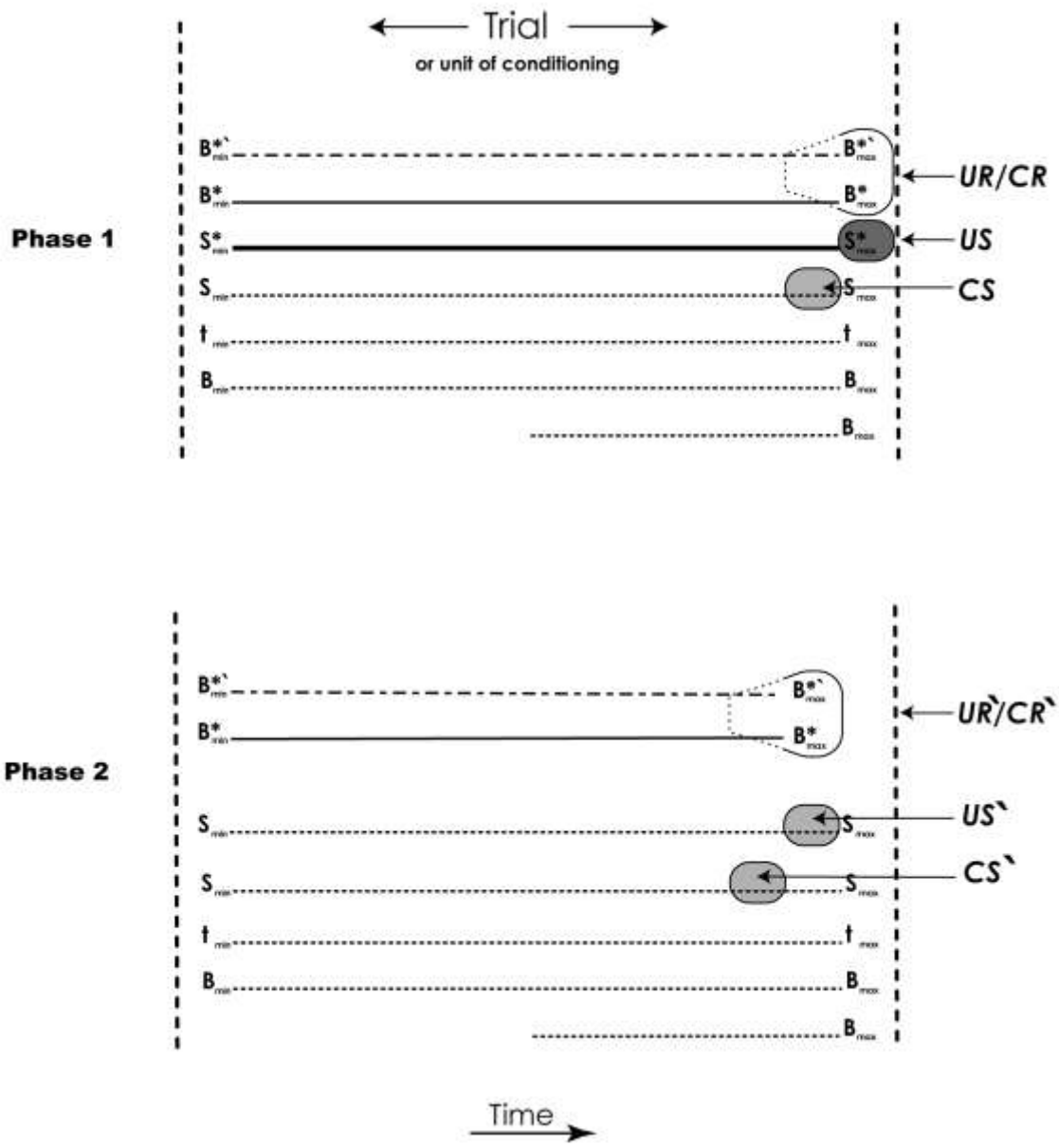
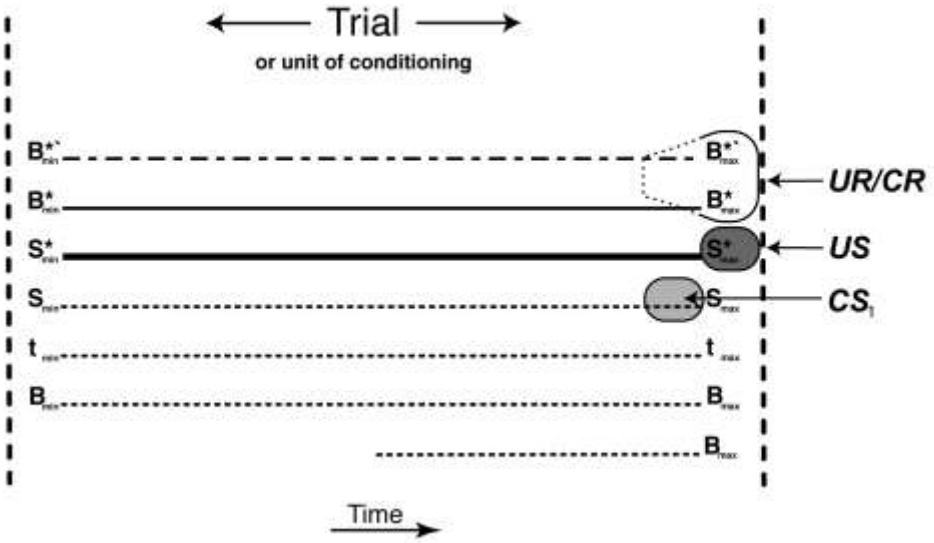



*Figure 12.20 A higher-order conditioning trial procedure is one in which during the first phase* $CS_1$ *is generally presented immediately preceding the US. In Phase 2, no US is presented, rather* $CS_1$ *is presented immediately after a novel CS. In effect, the previously conditioned* $CS_1$ *is used as a US.*

In a higher-order conditioning procedure, after $CS_1$ is conditioned with the US in Phase 1 (upper portion of the figure), $CS_1$ is then used as the reinforcer for a second different CS in Phase 2. Note the absence of $S^*_{min}$ - $S^*_{max}$ in the lower frame of Figure 12.20. The unconditioned stimulus $S^*_{max}$ is the reinforcer in Phase 1 while a higher-order conditioned reinforcer $S_{max}$ is the reinforcer in Phase 2. In this case, the $S_{min}$ - $S_{max}$ interval and $S_{max}$ would be functioning as the $S^*_{min}$ - $S^*_{max}$) and $S^*_{max}$.

## 11. Blocking

**Phase 1**




**Phase 2**

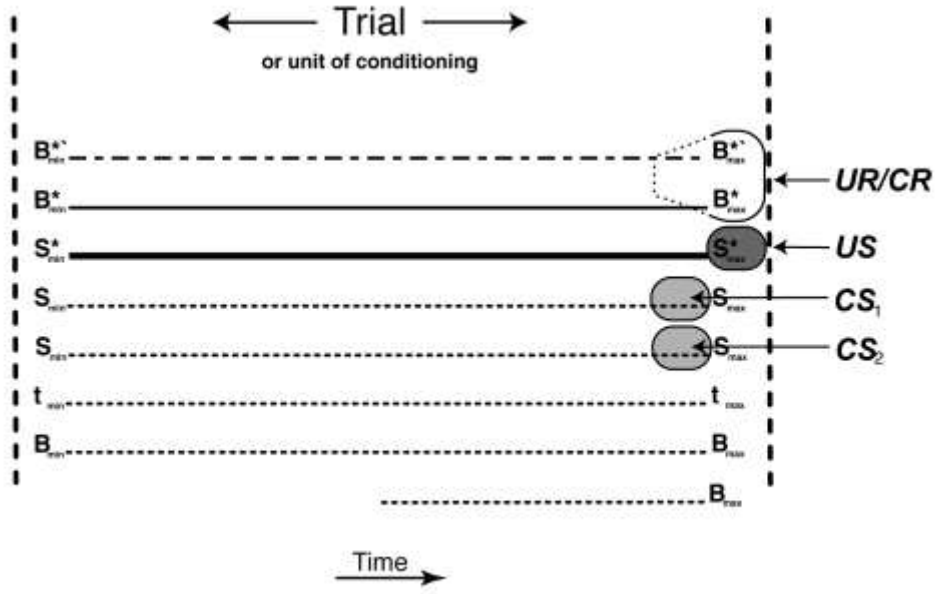



*Figure 12.21 A procedure in which a previously conditioned stimulus (*$CS_1$*) is presented in a compound with a novel stimulus (*$CS_2$*).*

In a blocking procedure or paradigm, a previously conditioned stimulus is presented as one of the compound stimuli in a subsequent conditioning procedure. The finding is that little conditioning occurs to the novel CS in Phase 2. $CS_1$ is said to block conditioning to $CS_2$.

## 12. Inhibition

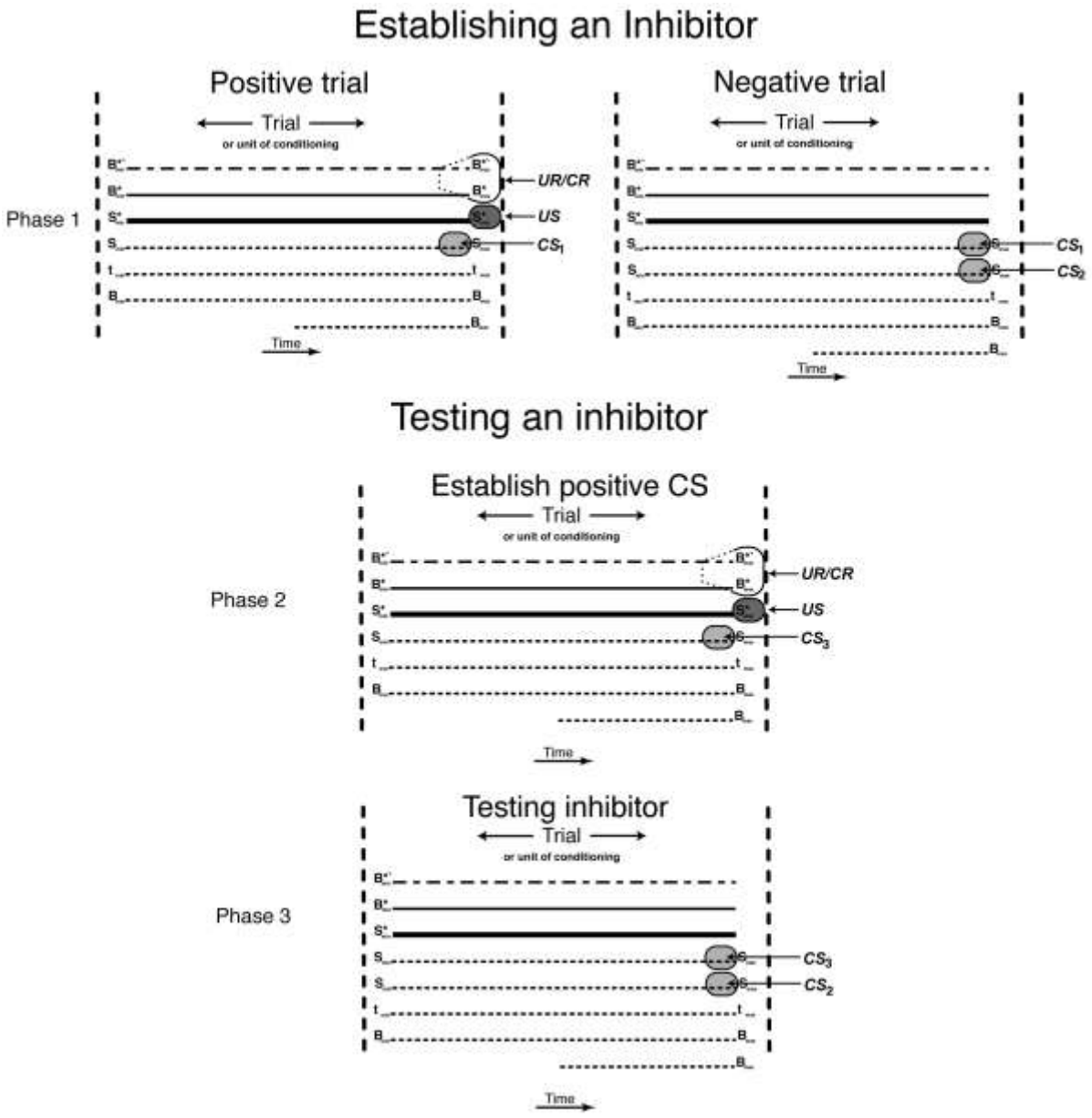



*Figure 12.22 In Phase 1, some trials present $CS_1$ followed by the US, during other trials $CS_1$ is accompanied by $CS_2$ and no US is presented (i.e., $CS_2$ designates an extinction trial). In a separate procedure, a novel stimulus ($CS_3$) is conditioned. Subsequently, $CS_2$ and $CS_3$ are presented as a compound with no US.*

In a conditioned inhibition procedure: 1) a stimulus CS1 preceeds food; 2)A stimulus CS2 is a differential compound cue of extinction in a discrimination procedure; (upper two frames of Figure 12.22 3).when CS2 is presented alone there is responding, when CS1 is presented with CS2 there is no responding with CS1[no responding occurs ). the cue for extinction when presented with a well-conditioned stimulus reduces or inhibits the conditioned response to the well-conditioned stimulus.

# CHAPTER 13

# The Emergence or Expression of Functional Relationships Between Arbitrary Stimuli and Arbitrary Responses: "Thorndikian Conditioning"

## I. Introduction

## II. Review: Procedures Resulting in an Arbitrary Stimulus Coming to Control an Arbitrary Response

A. Thorndikian conditioning procedure as a correlation
B. Schematic of Thorndikian conditioning procedure and results
   1. Traditional conceptualization of procedure and results of Thorndikian conditioning
   2. Bipolar conceptualization of procedure and results of Thorndikian conditioning
C. Specific instantiations of Thorndikian conditioning
   1. Simplistic step-by-step example of Thorndikian conditioning
   2. A more complete phase-by-phase example of Thorndikian conditioning
D. Direct and indirect assessment of Thorndikian conditioning
   1. Documenting the emergence or acquisition of Thorndikian conditioning: a semi-permanent change in behavior as a function of experience with a Thorndikian contingency
   2. Comparing the expressions of Thorndikian conditioning: the difference in asymptotic behavior as a function of the difference in Thorndikian contingencies

## III. Conceptual Precursor: Terminology Applicable to Thorndikian Conditioning

## IV. Factors Involved in Thorndikian Conditioning

A. Elements involved in Thorndikian conditioning
   1. Arbitrary behavior ($B_{max}$) ($B_{min}$ - $B_{max}$)
      a. Level at which the measure is taken
         i. External

ii. Internal
b. Defining characteristic of the arbitrary behavior
i. Topological properties
ii. Functional properties
c. Manifestation of the arbitrary behavior
i. Occurrence of the behavior
ii. The absence of the behavior

2. Arbitrary stimulus, including time ($S_{max}$) ($t_{max}$) ($S_{min}$ - $S_{max}$) and ($t_{min}$ - $t_{max}$)
a. Source of arbitrary stimulus
i. External
ii. Internal
iii. Time
b. Manifestation of the arbitrary stimulus
i. Presentation
ii. Removal
3. Fixed behavior ($B^*_{max}$) ($B^*_{min}$ - $B^*_{max}$) and ($B^{*\prime}_{min}$ - $B^{*\prime}_{max}$)
4. Subsequent outcome ($S^*_{max}$) ($S^*_{min}$ - $S^*_{max}$)
a. Origin of functional significance of subsequent outcome
i. Phylogenic
ii. Ontogenic
b. Vector or direction of control of the subsequent outcome
i. Appetitive
ii. Aversive
c. Manifestation of the subsequent outcome
i. Presentation
ii. Removal
5. Type of contingency governing the correlation of the arbitrary stimulus gradient ($S_{min}$ - $S_{max}$) with the subsequent outcome gradient $S^*_{min}$ $S^*_{max}$ or $S^*_{max}$
a. Direct contingency
i. Static contingency
ii. Dynamic contingency
iii. Indirect contingency
6. Type of contingency governing the correlation of the arbitrary behavior ($B_{min}$ - $B_{max}$) or only $B_{max}$ with $S^*_{min}$ $S^*_{max}$ or only $S^*_{max}$
a. Direct contingency
b. Indirect contingency

B. Preeminence of the correlation of the subsequent outcome with antecedent events in short time scale adaptation
1. Conceptualizations of classes of $B_{max}$ $S^*_{max}$ correlations or contingencies and their Outcome
2. Glossary of classes of $B_{max}$ $S^*_{max}$ correlations

## V. Procedures for Research on Thorndikian Conditioning or "Schedules of Thorndikian Reinforcement"

A. Methodological Issues Pertaining to Thorndikian Conditioning
1. General methodological approach
a. Instrumental conditioning
b. Operant conditioning
2. Subjects / apparatus/ procedures in Thorndikian research
a. Subjects
i. Thorndikian conditioning with pigeons
ii. Thorndikian conditioning with rats
b. Apparatus
i. Apparatus for pigeons
ii. Apparatus for rats
c. Procedures
i. Paradigmatic measures
(a) validity of measure referent
(b) applicability of measure referent
3. Data in Thorndikian research: dependent measures
a. Rate of response
i. Graphical display technology for depicting moment-to-moment changes in rate: the cumulative record
b. Ratio of different behaviors
c. Latency
d. Resistance to change
i. Acquisition
ii. Momentum
iii. Extinction
e. Interresponse time

B. Schedules to evaluate Thorndikian contingencies
1. Contingencies to examine the role of response count and the passage of time at $S^*_{max}$
a. Glossary of Schedules That Control the Correlations of Properties of $B_{max}$ and $t_{max}$ with $S^*_{max}$
b. Glossary of Additional Schedules
c. Classification of Schedules of Reinforcement by Contingency
i. Reinforced Response in Context of Constant Value of Single Parameter
ii. Reinforced Response in Context of Variable Value of Single Parameter
iii. No Specific Behavior "Reinforced" (Non-Contingent "Reinforcement")
2. Contingencies to compare the expression of different schedules within the same session
a. Glossary of Concatenated Schedules of Thorndikian Reinforcement

3. Contingencies of Reinforcement to examine the effect of when the Subsequent Outcome is itself a schedule
   a. Glossary of serial Schedules of Thorndikian Reinforcement
4. Summary of concatenated and serial schedules
5. Procedures or Schedules for Evaluating Competing Correlations, or Schedules That Provide Competing Reinforcers for Competing Behaviors
   a. Simple concurrent schedule
   b. Dynamic concurrent schedule
   c. Dynamic concurrent schedule with a shift cost
   d. *N* option concurrent schedule
   e. Concurrent chains schedule

## VI. Practical Experience Doing EAB

A. The point or goal of analyzing the data from an experiment
B. Example research
   1. IRT by time in interfood interval
   2. IRTn by IRTn-1

# CHAPTER 13

# The Emergence or Expression of Functional Relationships Between Arbitrary Stimuli and Arbitrary Responses: "Thorndikian Conditioning"

## I. Introduction

In this chapter, we will cover one class of short time scale organismic adaptation. In this class of conditioning, an arbitrary stimulus comes to semi-permanently control an arbitrary response. This process of establishing a new control over a behavior has been labeled trial-and-error learning; instrumental conditioning, operant conditioning, and Thorndikian conditioning.

Figure 13.1 illustrates the context of short time scale adaptation (A), the various classes of short time scale adaptation depicted as layers of a cube with the class of adaptation covered in the present chapter noted with gray (B). The details of the correlation that causes Thorndikian conditioning are represented in C, D, and E. Finally a direct and an indirect way to assess short time scale adaptation is shown in Section F.

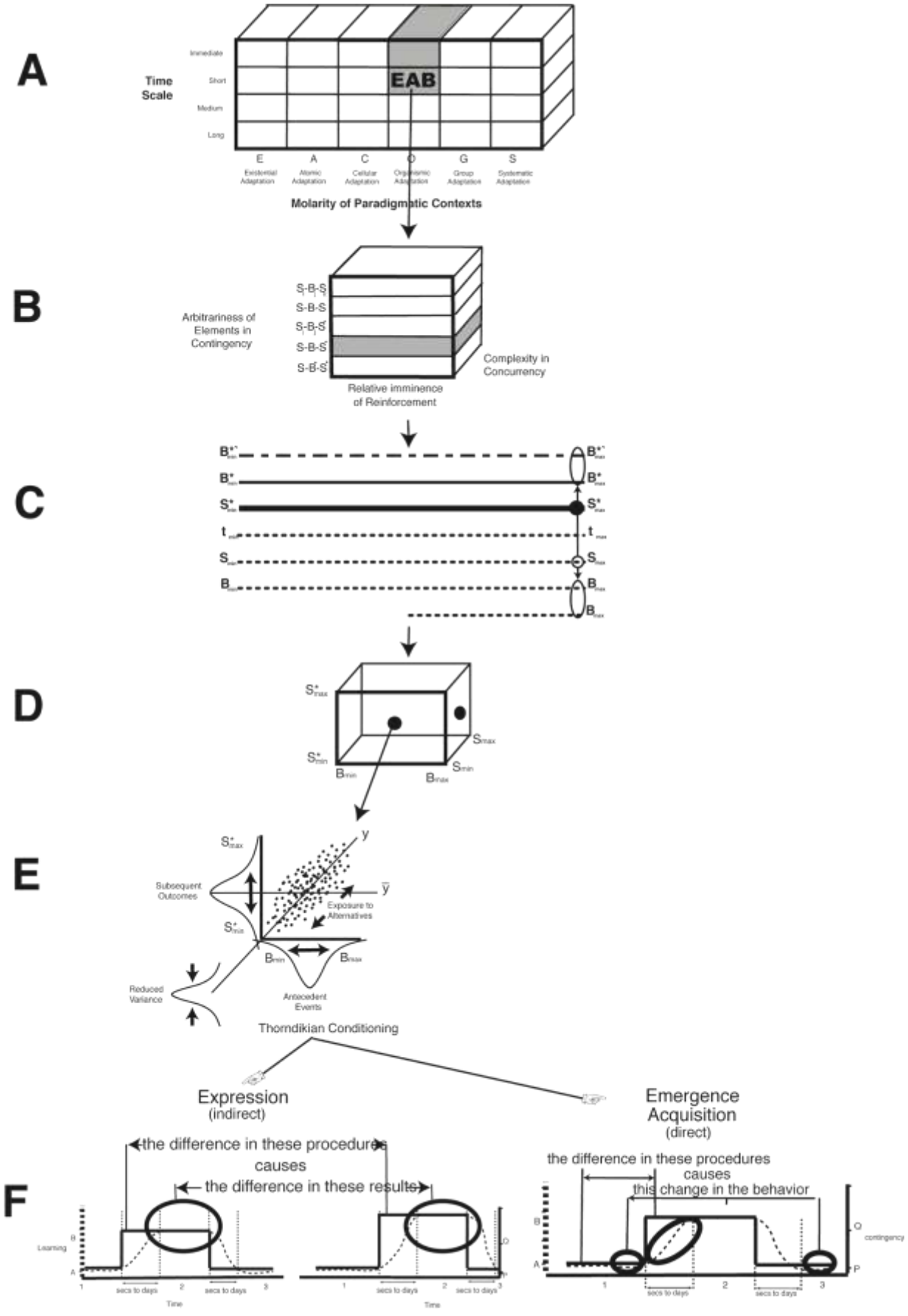

A
Time Scale
Immediate
Short
Medium
Long
EAB
E
A
C
O
G
S
Existential Adaptation
Atomic Adaptation
Cellular Adaptation
Organismic Adaptation
Group Adaptation
Systematic Adaptation
Molarity of Paradigmatic Contexts
B
Arbitrariness of Elements in Contingency
S-B-S
Complexity in Concurrency
Relative imminence of Reinforcement
C
D
E
Subsequent Outcomes
Exposure to Alternatives
Reduced Variance
Antecedent Events
Thorndikian Conditioning
Expression
(indirect)
Emergence
Acquisition
(direct)
F
the difference in these procedures causes the difference in these results
the difference in these procedures causes this change in the behavior
Learning
Time
secs to days
contingency

*Figure 13.1 illustrates the context of short time scale adaptation (A), the various classes of short time scale adaptation depicted as layers of a cube with the class of adaptation covered in the present chapter noted with gray (B). The details of the correlation that causes Thorndikian conditioning are represented in C, D, and E. Finally a direct and an indirect way to assess short time scale adaptation is shown in Section F.*

In Thorndikian conditioning, an arbitrary stimulus gradient (i.e., $S_{min}$ - $S_{max}$) comes to control an arbitrary behavior gradient (i.e., $B_{min}$ - $B_{max}$) as the result of elements of the stimulus and behavior gradient being correlated with the same portions of the $S^*_{min}$ - $S^*_{max}$ gradient.

More simplistically put, an arbitrary stimulus (e.g., $S_{max}$) comes to control an arbitrary behavior (e.g., $B_{max}$) as the result of the correlation of the behavior with an arbitrary stimulus ($S_{max}$) and a subsequent reinforcer ($S^*_{max}$).

If a pigeon is given food after key pecks, then the pigeon will come to peck at a high rate. But that scenario is a bit simplistic. If a pigeon is given food for pecking slowly, then it will peck slowly. So, a more precise statement would be that the probability of the reinforced behavior increases even though the pecking is occurring at a lower rate.

In principle, $S_i$s can be any stimuli the organism is capable of detecting, and the responses ($B_i$ s) can be any behavior the organism is capable of emitting and $S^*_i$ s can be any functionally significant event. Note that "conscious awareness" of any aspect of this process is irrelevant to the conditioning. People can be conditioned to do things that they are totally unaware of. In fact, the learned functional relationship could be entirely internal such as the control of blood pressure.

## II. Review: Procedures Resulting in an Arbitrary Stimulus Coming to Control an Arbitrary Response

This material is re-presented because it is absolutely essential to clearly understand. By now you should be able to briefly look at the figures and text and then step through the point of each on your own. Use this opportunity to strengthen your understanding through rehearsal. Keep in mind that the point of education is for you to see the dolphin not simply mouth the word "dolphin". Return to the original extended presentation if any of the issues covered are not perfectly clear.

### A. Thorndikian Conditioning Procedure as a Correlation

This material was first presented following Figures 10.9 and 10.10.

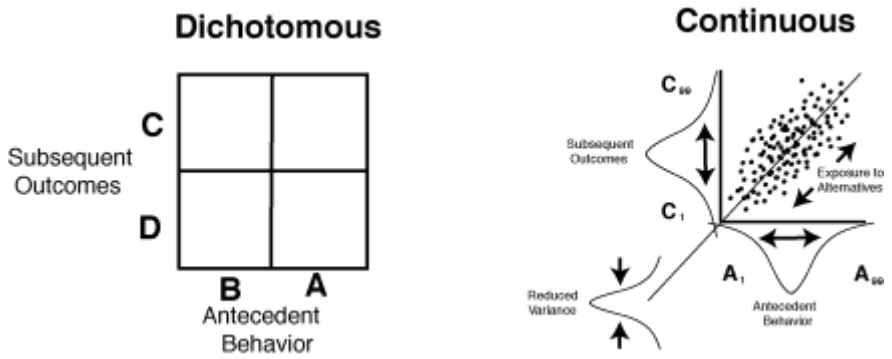



*Figure 13.2 The conjunctions between antecedent behaviors and subsequent outcomes necessary for Thorndikian conditioning are depicted in a dichotomous (left) and continuous (right) format*

In a typical exemplar of Thorndikian conditioning, the antecedent events are pecking and not pecking, and the subsequent outcomes are food presentation and no food presentation. The simple dichotomous case is illustrated in the left portion of Figure 13.2, while the right portion illustrates the case with a continuous behavior and a continuous outcome.

### B. Schematic of Thorndikian Conditioning Procedure and Results

#### 1. Traditional Conceptualization of Procedure and Results of Thorndikian Conditioning

This material was first presented following Figure 9.18. Figure 13.3 provides the traditional timing diagram conceptualization of Thorndikian conditioning and its resulting semi-permanent change in the terminal behavior

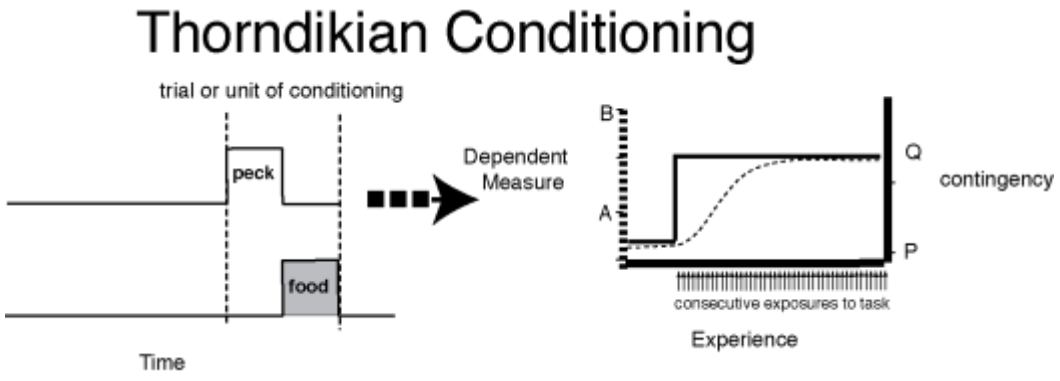



*Figure 13.3 A traditional illustration of Thorndikian conditioning. The left portion of the figure depicts a Thorndikian training procedure. Pecks are followed with food presentation. The right portion of the figure illustrates, that with many experiences with the Thorndikian training procedure, the behavior that had been followed by the reinforcer increases in probability up to an asymptotic limit as a result of that contingency.*

### 2. Bipolar Conceptualization of Procedure and Results of Thorndikian Conditioning

Figure 13.4 provides a depiction of the bipolar correlation conceptualization of a Thorndikian conditioning trial (left frame) and a bipolar version of its obtained results (right frame). In simple term it is a continuous version of the dichotomous version of the procedure and results presented in figure 13.3. The contextual framework for this conceptualization was established following figure 10.12 (left portion of figure 12.4) and following figure 9.21 9.23 and 9.26 (right frame of figure 13.4). Paradigmatically stated: The $S^*_{min}$ - $S^*_{max}$ gradient enables the $S_{min}$ - $S_{max}$ gradient to semi-permanently control the expression of $B_{min}$ - $B_{max}$ and /or instances of $B_{max}$.

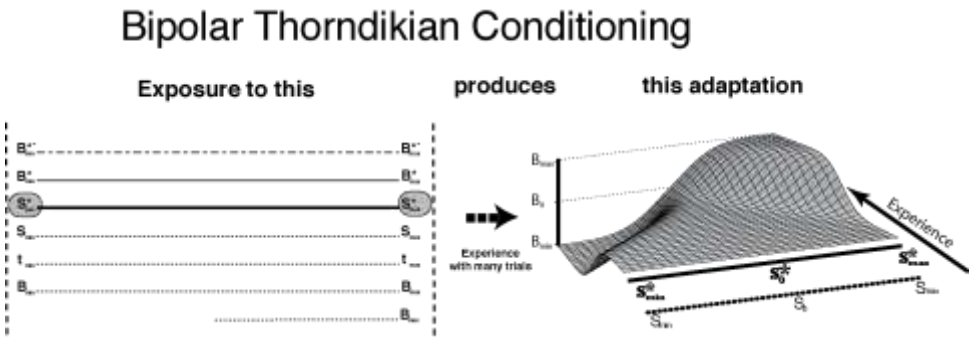



*Figure 13.4 A linear representation of the enforced correlations in Thorndikian conditioning with the traditional terminology appended is presented in the left portion of the figure. The right portion of the figure depicts the behavior across the entire interfood interval as a function of experience with the schedule of reinforcement. The z-axis portrays the emergence of the behavior with experience while the x-axis portrays the emergence of the asymptotic behavior to be expected.*

## C. Specific Instantiations of Thorndikian Conditioning

### 1. Simplistic Step-by-Step Example of Thorndikian Conditioning

This material was first presented following Figure 9.19. Note that as is indicated on the right edge of the figure, the functional relationship controlled by the amber light was semi-permanently changed. What was initially a low rate or non-existent behavior now reliably occurs to the stimulus that had been in effect.

| | Stimulus Context | Antecedent Behavior | Subsequent Outcome | Obtained Behavior | |
|---|---|---|---|---|---|
| **Baseline** Phase 1 | amber | nothing | nothing | nothing | |
| **Conditioning** | amber | nothing | nothing | nothing | |
| **or** | amber | look | food | look | |
| **treatment** | amber | peck | food | peck | Evidence of short-term adaptation or learning |
| **phase** | . | . | . | | |
| Phase 2 | . | . | . | | |
| | . | . | . | | |
| | amber | peck | food | peck | |
| **Test** | amber | peck | nothing | peck | |
| Phase 3 | amber | peck | nothing | peck | |
| | amber | nothing | nothing | nothing | |

*Figure 13.5 A simplistic illustration that as the result of following a behavior with food presentation, the behavior increases in rate. Initially during the baseline, before the conditioning procedure, the amber light controls no pecking. When key pecks are followed by food presentation, amber comes to control key pecking even when food no longer follows those key pecks*

### 2. A More Complete Phase-by-Phase Example of Thorndikian Conditioning

This material was first presented after 9.20. Note that as is indicated on the right edge of the figure, the functional relationship controlled by the amber light has semi-permanently changed. What was initially a low rate or non-existent behavior now reliably occurs to the stimulus that had been in effect.

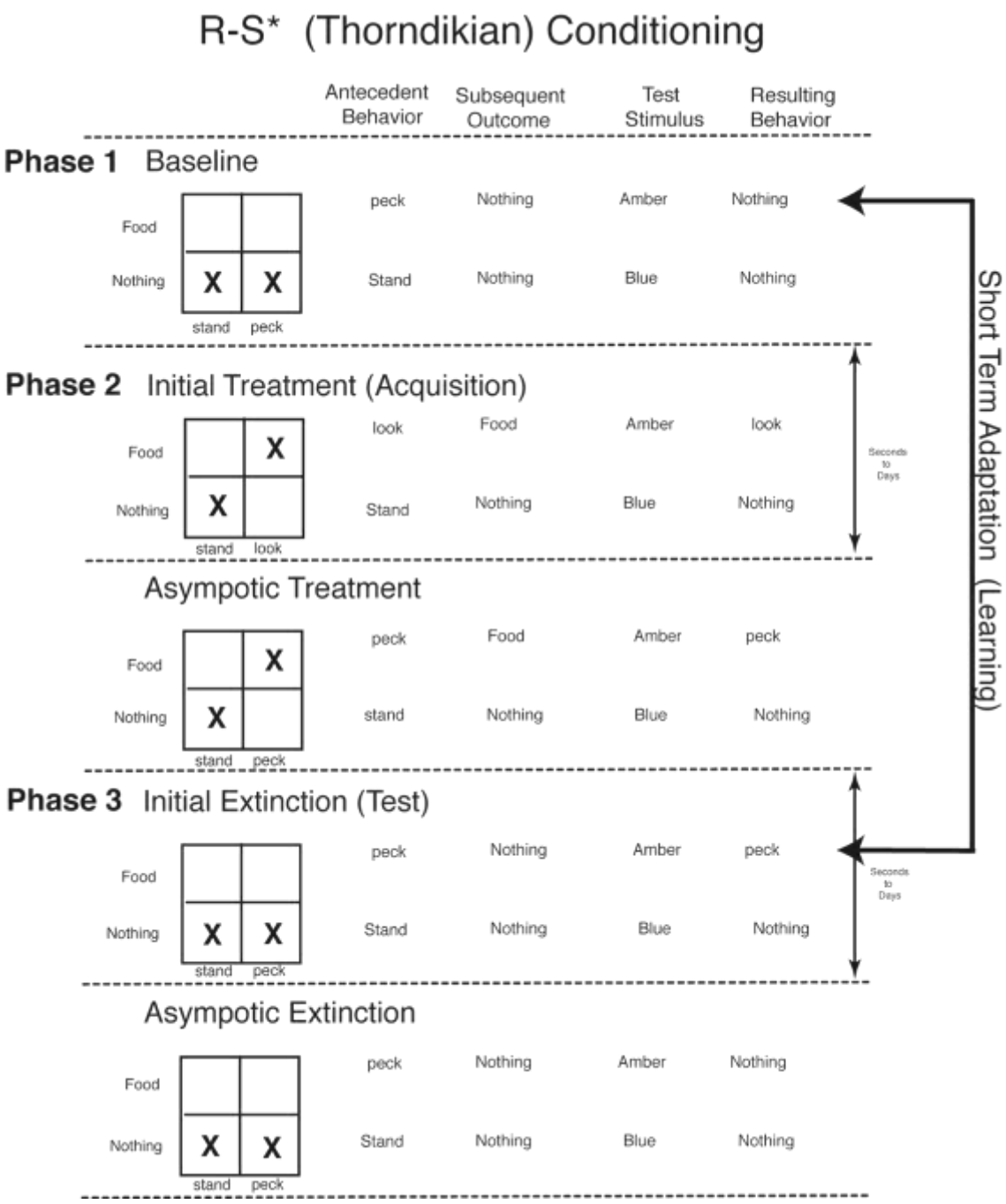



*Figure 13.6 An illustration of a specific instantiation of Thorndikian conditioning. The left portion of each row depicts the procedure to which the animal is exposed as a 2x2 contingency table. The next two columns provide the antecedent behavior and subsequent outcomes specified in the contingency table. The fourth column provides the test stimulus that was in effect when the peck food conjunction occurred and the fifth column provides the behavior controlled by the contextual stimulus. The top or fifth row labeled baseline shows no reaction when the amber stimulus is first presented. Following the conditioning procedure in which key pecks are reinforced (rows labeled initial and asymptotic treatment), amber can be seen to control key pecking even when no food no longer follows those pecks in the second row labeled initial extinction.*

### D. Direct and Indirect Assessment of Thorndikian Conditioning

#### 1. Documenting the Emergence or Acquisition of Thorndikian Conditioning: a Semi-Permanent Change in Behavior as a Function of Experience with a Thorndikian Contingency

This material( figure 13.7) was first presented following Figure 1.18 and 9.4. "The pigeon learning" or the emergence of a behavior to a stimulus such as pecking a green key that is being reinforced with a Thorndikian procedure is monitored across repeated exposures to that contingency. If the behavior of the pigeon changes from doing nothing to a new behavior such as pecking the green key and that new functional relationship shows short time scale hysteresis on the onset and offset of the contingency, then that behavior change is an example of short time scale adaptation.

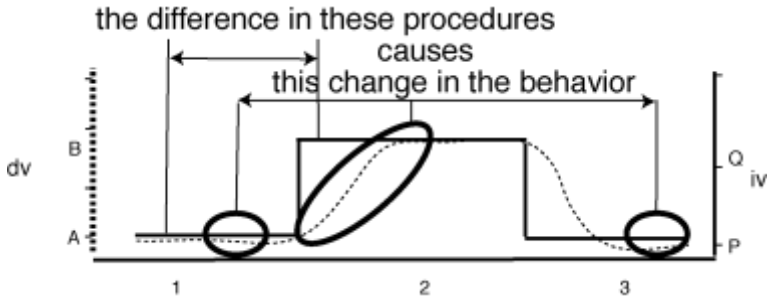



*Figure 13.7 This figure depicts the emergence or acquisition in a dependent variable (dotted line) as a function of a change in the independent variable (solid line). In sum, the change or difference in the dependent measure is caused by the difference in the independent variable. The initial state of behavior (in the absence of the treatment) is seen to be recovered at Time 3 when the independent variable is removed.*

#### 2. Comparing the Expressions of Thorndikian Conditioning: The Difference In Asymptotic Behavior as a Function of the Difference in Thorndikian Contingencies

This material (figure 13.8) was first presented after figure 1.19 and 9.5. The asymptotic expression of a behavior to a stimulus such as pecking a green key that is being reinforced in a Thorndikian procedure is compare to the asymptotic expression of the behavior to some other contingency such as when the behavior is reinforced twice as often. If the two behaviors show hysteresis on the onset and offset of those contingencies, then the difference in the behavior is short time scale adaptation and can be attributed to the differences in those contingencies.

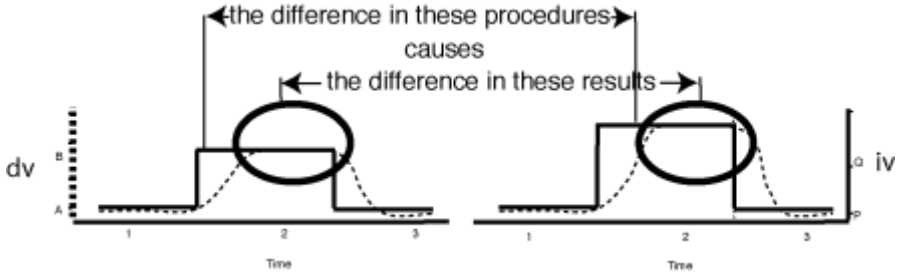


*Figure 13.8 This figure depicts the difference in the asymptotic expression or performance of a dependent variable (dotted line) as a function of a difference in the independent variable (solid line). In sum, the difference in the dependent variable is caused by the difference in the independent variable.*

# III. Conceptual Precursor: Terminology Applicable to Thorndikian Conditioning

**Ad lib weight**

This is an animal's weight when it has free access to food and water in its home cage. This weight of the animal is typically higher than when it is free ranging.

**Baseline**

The stable behavior before a treatment is applied, and following the removal of the treatment. It is analogous to the tare weight of a container.

**Blackout**

A totally dark condition during which no reinforcer is available. It is meaningful in research with pigeons because the pigeon virtually stops behaving when it is in the dark. This procedure should not be confused with a timeout – see below. Additionally, this procedure would be relatively meaningless if used on bats.

**Component**

One portion of a complex schedule during which a single reinforcement schedule is implemented, for example, the VI component of a multiple schedule.

**Conditioned Reinforcement**

A reinforcer whose effectiveness is established as the result of that stimulus' association with an effective reinforcer. For example, a click after having been correlated with subsequent food presentation will function as a reinforcer.

**Discrimination**

1. a procedure in which two discriminably different schedules are presented, each during a discriminably different stimulus.
2. the degree to which a behavior is different in two different conditions

**Experimental Chamber**

An enclosed workspace that is as light tight, sound attenuating, and as free from disturbances as is practical to obtain.

**Generalization**

A similarity in behavior to two different procedures where the similarity of behavior is a function of the similarity of the situations

**House light**
A general illumination source that is typically on throughout the entire experimental procedure except during reinforcement.

**Latency**
The elapsed time from some designated marker such as a stimulus onset, to the occurrence of a designated response.

**Magazine**
The container that holds whatever is made available to the subject as a reinforcer, most typically food.

**Magazine Training**
The process whereby the animal is shaped to quickly go to the magazine and eat from it whenever it is made available.

**Operandum**
The device that detects the behavior of the animal that is counted as a response.

**Pause**
A temporary cessation in responding.

**Rate**
The number of responses per unit of time.

**Respondent**
A respondent is an innate or fixed response to a fixed stimulus elicitor. It is the response component of a functional relationship between a controlling stimulus and a controlled response established by evolution. In behavior analytic research, it is most often, but not necessarily, a reflex response. The term would typically designates the $B^*_{max}$ or $B^{*\prime}_{max}$ element of a $B^*_{min}$ - $B^*_{max}$ or $B^{*\prime}_{min}$ - $B^{*\prime}_{max}$ gradient as opposed to an element from the $B_{min}$ - $B_{max}$ gradient.

**Satiation**
1. The termination of consumption following the "sufficient" consumption of food, water, or sex.
2. The result of an abolishing operation with respect to a consummatory reinforcer.
3. The label for the internal state said (tautologically) to cause the above behavior change.

**Shaping**
The successively adjusting behavior requirement for reinforcement that successively shifts the measure or topography of a behavior toward some specified distribution.

**Steady State**

The eventual stable behavior measure or equilibrium that develops over time following sufficient exposure to a contingency. This is also called an asymptotic performance. Note that substantial high and low frequency changes (i.e., asynchronous dynamics) can endure for at least a year (and possibly permanently) in the absence of any change in the programmed reinforcement contingencies.

**Timeout**

A signaled condition during which an ongoing reinforcement contingency is suspended.

**Warm up**

The change in behavior at steady state when the contingencies are first applied after a period without those contingencies being in effect. The prototypical example is the behavior change at the beginning of each daily session, and especially on a Monday following a weekend of the absence of exposure to the contingencies.

**IRT**

InterResponse Time. The time between one response and the next. This measure is also an index of probability or rate in that short IRTs result in a high rate and long IRTs result in a low rate.

**Operant**

A behavior that has what is often labeled a "voluntary" origin. An example would be knocking on a door or going fishing.

Typically, the term would designate the $B_{max}$ element of a gradient as opposed to the entire $B_{min}$ - $B_{max}$ gradient.

More comprehensively, it is the $B_{min}$ - $B_{max}$ gradient.

**$S^D$**

Pronounced "ess dee," it is a positive discriminative stimulus in a dichotomous context. Most typically, it is explicit and easily discriminable. It is the stimulus in whose presence an operant behavior may be reinforced.

More comprehensively, any stimuli associated with the second half of an $S^*_{min}$ - $S^*_{max}$ gradient.

**$S^\Delta$**

Pronounced "ess delta," it is a negative discriminative stimulus in a dichotomous context. Most typically, it is explicit and easily discriminable. It is the stimulus in whose presence an operant behavior will not be reinforced.

More comprehensively, any stimuli associated with the first half of an $S^*_{min}$ - $S^*_{max}$ gradient.

**Trial**

A unitary learning experience. It is across increasing numbers of this unit that learning with experience is said to take place. Most typically it ends with a

functionally significant subsequent outcome. For example, exposure to a schedule of reinforcement ending in a reinforcer such as a single iteration of an FR50. Typically, it is synonymous with the interreinforcer interval. In principle, a trial could be used to refer to a link in a multiple schedule even if no reinforcers (or multiple reinforcers) occurred on that particular exposure (e.g., 1 minute exposure to a VI 30-sec schedule in a multiple schedule where the links were 1 minute long) or a 45 second extinction link in a multiple schedule. In broad strokes, the core idea is a unitary learning experience.

**Interfood Interval**

The time between one reinforcer and the next reinforcer when the outcome is food in a concatenated-trials procedure.

More comprehensively, the $S^*_{min}$ - $S^*_{max}$ interval when $S^*_{max}$ is food.

**Reinforcement Contingency**

The specification of the elements correlated with $S^*_{max}$. Most precisely, the entire set of elements designated in Figure 10.12. Alternatively stated, the conditions obtained as the result of a schedule of reinforcement. Most typically, this term refers to only Thorndikian contingencies, but that is not necessarily the case. It also refers to a Pavlovian reinforcement contingency such as, for example, a short delay conditioning procedure.

**Schedule of Reinforcement**

The correlations between the $S^*_{min}$ - $S^*_{max}$ gradient and arbitrary behaviors, stimuli, and time. Most typically it is instantiated as the result of specific procedures that assures particular conjunctions are in place at the moment of $S^*_{max}$ (reinforcement). For example, a fixed-ratio 50 schedule assures that the reinforced response will always occur in the presence of 49 prior responses since some marker (most typically the previous food presentation in concatenated procedures). A variable interval schedule assures that the reinforced response will occur in the presence of (or no sooner than) a variable set of times since some marker. More comprehensively, a schedule of reinforcement refers to all correlations that occur as the result of the instantiation of a $S^*_{min}$ - $S^*_{max}$ gradient. Most typically, the term "schedule of reinforcement" refers to only Thorndikian contingencies, but it could equally refer to a schedule of Pavlovian reinforcement.

**$S^*_{min}$ - $S^*_{max}$ Gradient**

The gradient of "value" in a schedule of reinforcement from the point of least imminence or probability with the subsequent outcome to the point of maximum imminence or probability with the subsequent outcome.

**$S_{min}$ - $S_{max}$ Gradient**

The gradient of arbitrary stimuli correlated with the $S^*_{min}$ - $S^*_{max}$ gradient.

**$t_{min}$ - $t_{max}$ Gradient**

The gradient of time correlated with the $S^*_{min}$ - $S^*_{max}$ gradient.

**$B_{min}$ - $B_{max}$ gradient**

The gradient of arbitrary behavior correlated with the $S^*_{min}$ - $S^*_{max}$ gradient .

**$B_{max}$ , or $B_{max}$ gradient**

Instances of the specific arbitrary behavior correlated with $S^*_{max}$. This behavior also tends to occur earlier in the $S_{min}$ - $S_{max}$ interval than immediately preceding $S^*_{max}$, and typically does not occur in the initial portion of an $S^*_{min}$ - $S^*_{max}$ interval.

# IV. Factors Involved in Thorndikian Conditioning

Thorndikian conditioning occurs as the result of the correlation of antecedent behavior and subsequent outcomes. The behavior gradient ($B_{min}$ - $B_{max}$) is controlled by the stimulus gradient ($S_{min}$ - $S_{max}$) and temporal gradient ($t_{min}$ - $t_{max}$) as the result of those three gradients being correlated with the $S^*_{min}$ - $S^*_{max}$ gradient. The label for the procedure used to create/enforce those correlations is "schedule of Thorndikian reinforcement" regardless of whether it is naturally occurring or is deliberately implemented by someone. It should be noted that schedules of reinforcement were developed as analytical tools with which phenomenon could be understood by controlling important causal factors rather than as instantiations of everyday situations in the laboratory where they could be examined

## A. Elements Involved in Thorndikian Conditioning

### 1. Arbitrary Behavior ($B_{max}$) ($B_{min}$ - $B_{max}$)

This behavior is the dependent measure in Thorndikian procedures. Note that most typically, only instances of $B_{max}$ are recorded however more completely the behavior is the $B_{min}$ - $B_{max}$ gradient. The logic in a typical operant analysis is exclusively "how does the rate of the behavior class which immediately precedes the reinforcer (i.e., $B_{max}$) change as a function of that conjunction of that behavior and reinforcement (i.e., $S^*_{max}$).

#### a. Level at which the measure is taken

Where is the thing being measured located.

##### i. External

This measure is an activity of the entire single organism that has an effect on the environment, prototypically, this would be a key peck or lever press in the research setting.

#### ii. Internal

Behaviors are presumed to be for the most part functionally equivalent. Behaviors that are easy to reliably record such as a key peck or a lever press are the behaviors of choice in EAB research. However, biofeedback is an area in applied behavior analysis and is based on providing external explicit reinforcers for an internal behavior such as blood pressure. The internal behavior is detected by some instrument such as electronic equipment designed to detect the behavior.

This class of behavior is the activity of cells or cell assemblies and is rarely represented in EAB conceptual schemes. Note that any reference to these internal behaviors as either independent or dependent variables require rigorous empirical support.

### b. Defining Characteristic of the Arbitrary Behavior

#### i. Topological Properties

The physical characteristics of the behavior such as a hand movement or utterance which exceeds some criterion.

#### ii. Functional Properties

The impact on the environment such as the operation of a response key.

### c. Manifestation of the Arbitrary Behavior

#### i. Occurrence of the Behavior

#### ii. The Absence of the Behavior

## 2. Arbitrary Stimulus, Including Time ($S_{max}$) ($t_{max}$) ($S_{min}$ - $S_{max}$) and ($t_{min}$ - $t_{max}$)

These are stimuli whose relevance to the conditioning procedure comes from their ontogenic correlation with some aspect of the $S^*_{min}$ - $S^*_{max}$ gradient rather than any phylogenic relationship. It could be argued that any stimuli that have a random relationship to the $S^*_{min}$ - $S^*_{max}$ gradient are "invisible" or provide the context within which all other stimuli stand out or exist. In Thorndikian procedures, the arbitrary stimuli include the negative ($S^{\Delta}$) and the positive ($S^{D}$) discriminative stimuli. More completely, this is the $S_{min}$ - $S_{max}$ and $t_{min}$ - $t_{max}$ gradient.

### a. Source of Arbitrary Stimulus

#### i. External

An external stimulus is any explicit stimulus in the environment. Prototypically, in the research setting a transilluminated key for pigeons

#### ii. Internal

Other than time, internal arbitrary stimuli are rarely examined in EAB because they cannot be easily turned on or off by the experimenter. The prototypical internal stimulus would be the stimulus consequences of high blood pressure as measured by some instrument used in biofeedback.

#### iii. Time

This is a problematic stimulus. It can be shown to be the most parsimonious explanation for some behavior (such as fixed interval behavior) but it cannot be manipulated like a key color. Typically, it is considered the same as an arbitrary stimulus as a pragmatic convenience.

### b. Manifestation of the Arbitrary Stimulus

#### i. Presentation

Prototypically, this would be turning on a keylight.

#### ii. Removal

Prototypically, this would be turning off a keylight.

## 3. Fixed Behavior ($B^*_{max}$) ($B^*_{min}$ - $B^*_{max}$) and ($B^{*'}_{min}$ - $B^{*'}_{max}$)

In Thorndikian procedures, fixed behaviors (B* and B*') are rarely measured and are almost always ignored because they are seen as irrelevant to the task of understanding how a consequence affects the rate of an operant (the raison d'etre of behavior analysis).

## 4. Subsequent Outcome ($S^*_{max}$) ($S^*_{min}$ - $S^*_{max}$)

Traditionally, this is seen as presenting or not presenting a reinforcer or an $S^*_{max}$. Functionally, it is the occurrence of any stimulus that creates the correlational structure illustrated in Figure 10.12. Several views could be offered as to why it has that effect. It could be said to be a stimulus with value, or as Donahoe and Palmer suggest a stimulus which controls a behavior adjustment. More completely, the subsequent outcome is best understood within the context established by it; i.e. the entire $S^*_{min}$ - $S^*_{max}$ gradient .

### a. Origin of Functional Significance of Subsequent Outcome

#### i. Phylogenic

These are typically labeled primary reinforcers.

#### ii. Ontogenic

These are typically labeled conditioned reinforcers. These reinforcers can be considered arbitrary reinforcers

### b. Vector or Direction of Control of the Subsequent Outcome

#### i. Appetitive

These outcomes control approach behavior.

#### ii. Aversive

These outcomes control avoidance behavior.

### c. Manifestation of the Subsequent Outcome

#### i. Presentation

The stimulus occurrence or its onset is the "outcome."

#### ii. Removal

The absence, or the offset of the stimulus is the "outcome."

## 5. Type of Contingency Governing the Correlation of the Arbitrary Stimulus Gradient ($S_{min}$ - $S_{max}$) With the Subsequent Outcome Gradient ($S^*_{min}$ - $S^*_{max}$) or $S^*_{max}$

### a. Direct Contingency

This factor is explicitly part of the contingency, and would therefore be enforced.

#### i. Static Contingency

This factor is the same with each repetition of the contingency such as the response count under an FR50.

#### ii. Dynamic Contingency

This factor can change with each occurrence of the scheduled contingency (e.g., the various interreinforcer times in a variable interval schedule).

#### iii. Indirect Contingency

This factor is a result of the direct contingency but is not explicitly enforced. Different direct contingencies such as an FR50 and an FR100 would be expected to have different indirect stimulus contingencies by virtue of the type of regularity resulting from that specific contingency. For example, an FR50 could take about 10 seconds to complete while an FR100 may take about 20 seconds to complete. Each schedule would have its directly reinforced FR contingency and its indirectly reinforced time-to-complete contingency. The variability in the time-to-complete an

FR50 and an FR100 would each have their own variations and they would be expected to adventitiously reach their own asymptotic limits.

### 6. Type of Contingency Governing the Correlation of the Arbitrary Behavior $B_{min}$ - $B_{max}$ or only $B_{max}$ With $S^*_{min}$ - $S^*_{max}$ or only $S^*_{max}$

#### a. Direct Contingency

This type of contingency directly specifies the details of the response which is associated with the reinforcer. For example, a response key explicitly and directly specifies the reinforced behavior.

#### b. Indirect Contingency

This factor is the result of the direct contingency enforced by the schedule of reinforcement but is not explicitly reinforced. An example of the effect of an indirect response contingency would be an FI schedule. For example, an FI 60 sec may have about 50 pecks in each interval while an FI 30 may have only 25 pecks per interval. These response counts would be indirectly reinforced in those FI schedules.

## B. Preeminence of the correlation of the subsequent outcome with antecedent events in short time scale adaptation

Of all the factors that affect short time scale adaptation, by far the greatest is the relationship between the antecedent events and the subsequent outcomes. The outcome following the key peck in Thorndikian procedures or the outcome and how that conjunction occurs accounts for the largest source of variance in Thorndikian organismic adaptation..

Schedules of Thorndikian reinforcement are analytical procedures to assure the conjunction of specific events at the moment of reinforcement, unfortunately however their groupings and labels sometimes reflect the evolution of their conceptualization and subsequent research popularity rather than their functional impact or an overall top down systematic conceptual structure.

It should be noted that schedules of reinforcement were developed as analytical tools with which phenomena could be understood by controlling important causal factors rather than as the instantiation of everyday situations in the laboratory where those everyday situations could be examined more thoroughly

### 1. Conceptualizations of Classes of $B_{max}$ $S^*_{max}$ Correlations or Contingencies and Their Outcome

As is illustrated in Figure 13.9, at the most basic level, $S^*_{max}$ could be the onset or offset of some event such as food or shock (y axis) and the result of that occurrence could be that $B_{max}$ increases or decreases in rate (x axis). In principle, the stimuli and

behaviors could be internal events or external events, just as in Pavlovian contingencies (presented in Figure 12.10), however internal (z axis) stimuli and internal behaviors are rarely studied in Thorndikian research. If for no other reason than they are far more difficult to transduce.

The labels for the four classes of external procedures and outcomes are provided in Figure 13.9. That external terminology is also used in the case of internal stimuli and reinforcers when the internal contingencies can be explicitly identified.

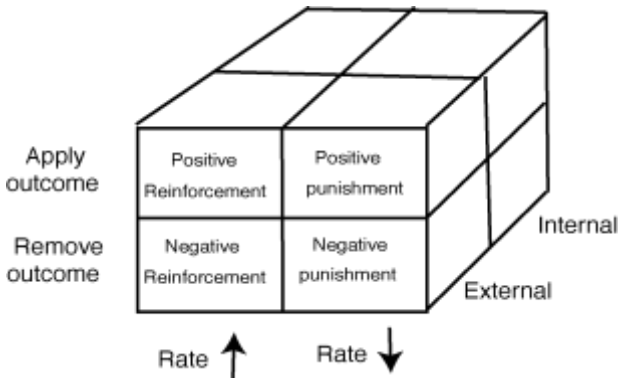



*Figure 13.9 A 2 x 2 x 2 contingency table illustrating the combinations of applying or removing an outcome with the effect of increasing or decreasing the subsequent rate. This figure is an analog of Figure 12.10 for Pavlovian contingencies. Applying an outcome that increases the rate is labeled a positive reinforcer. Applying an outcome that decreases the rate is labeled a positive punisher. Removing an outcome with the effect of increasing the rate is labeled a negative reinforcer, while removing an outcome with the effect of decreasing the rate is labeled negative punishment. The structure provides for outcomes that are internal or external in order to provide for a symmetrical framework with families of Pavlovian contingencies.*

The actual events and their relationships in these four typical classes of procedures and outcomes are depicted in the traditional format in Figure 13.10. The upper left quadrant shows a response (B) on the bottom line followed immediately by a reinforcer (S*) on the top line. This class of procedure and outcome is labeled positive reinforcement if the rate of the behavior increases. The lower left quadrant shows a response (B) immediately followed by the offset of an aversive stimulus (S*). If the rate of the response increases, this class of procedure and outcome is labeled negative reinforcement. The upper right quadrant shows a response (B) immediately followed by an aversive stimulus (S*). If the rate of response decreases, this class of procedure and outcome is labeled positive punishment. The lower right quadrant shows a behavior (B) followed immediately by the offset of an positive stimulus (S*). If the response rate decreases, this class of procedure and outcome is labeled negative punishment.

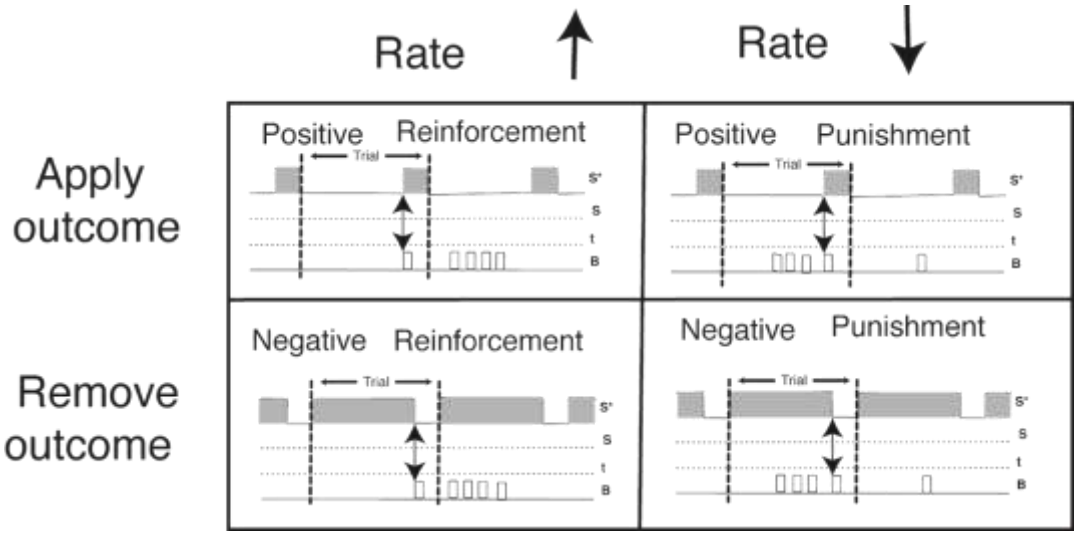



*Figure 13.10 A figure depicting the application or removal of an event as an outcome, and the subsequent increase or decrease in behavior in the traditional format.*

Figure 13.11 provides the same information as was depicted in Figure 13.10 However, in this case, the depiction is based on the correlation structure first introduced in Figure 10.12 rather than as a simple timing diagram

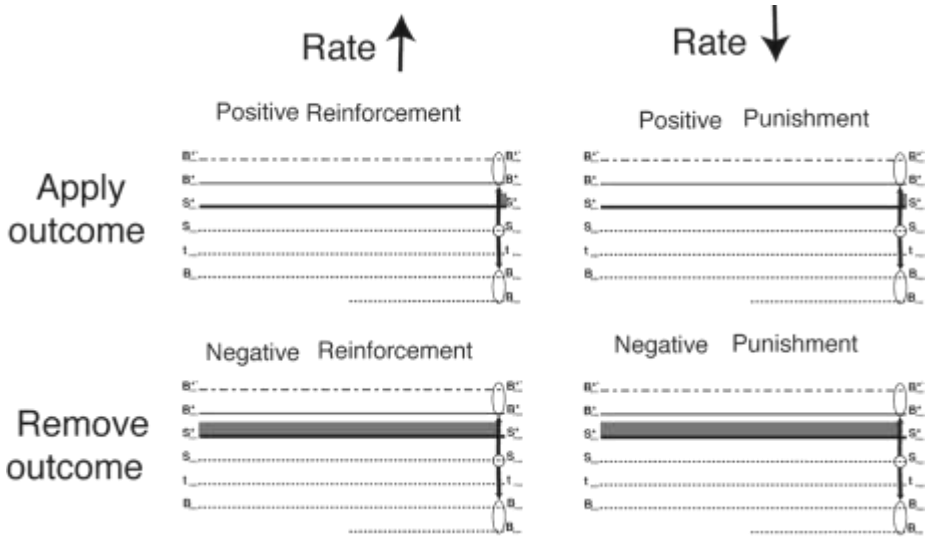



*Figure 13.11 A depiction of positive and negative reinforcement and punishment in the linear framework first presented in Figure 10.12.*

## 2. Glossary of Classes of $B_{max}$ $S^*_{max}$ Correlations

**Positive reinforcement**

The presentation of an event ($S^*_{max}$) that increases the rate of the immediately previous response class ($B_{max}$).

**Negative reinforcement**

Negative reinforcement is the removal of an event ($S^*_{max}$) that increases the rate of the immediately previous response class ($B_{max}$).

**Positive punishment**

Positive punishment is the presentation of an event ($S^*_{max}$) that decreases the rate of the immediately previous response class ($B_{max}$).

**Negative punishment**

Negative punishment is the removal of an event ($S^*_{max}$) that decreases the rate of the immediately previous response class ($B_{max}$).

# V. Procedures For Research on Thorndikian Conditioning or "Schedules of Thorndikian Reinforcement"

## A. Methodological Issues Pertaining to Thorndikian Conditioning

### 1. General Methodological Approach

There have been two basic procedures used to investigate the acquisition of control over arbitrary behavior by arbitrary stimuli. The two behavioral processes are at the most fundamental level the same, so for most purposes the terms are interchangeable. However, when used to refer to a distinct procedure as opposed to the other, the terminology is given below. In current usage, the general term for both procedures is Thorndikian or operant conditioning. Instrumental conditioning is now most often just one of many synonyms for Thorndikian conditioning.

#### a. Instrumental Conditioning

These procedures were most popular in the 1940s through to the late 1950s. They typically involved spatial movement behaviors such as problem box escape, maze learning or running in straight alleys. The behavior was generally interpreted from an internalistic perspective. The apparatus was an effort to provide a task that was similar to the subjects (rats) natural environment. These paradigms have been supplanted by lever pressing or key pecking procedures because instrumental conditioning apparatuses were cumbersome to use, confounds were not easy to control and they measured behavior that was seen as too molar. An interesting historical note is that some instrumental conditioning research reported the percentage of animals responding in particular ways as the result of the treatment that each animal in the experiment received. In this regard, this research had actually been on group adaptation or what is labeled sociology.

#### b. Operant Conditioning

These procedures became popular throughout all animal research in psychology in the early 1960s and had been the de facto standard in EAB since its inception. They involve testing conditions such as key pecking or lever pressing where little spatial movement occurred and the behavior of interest was the repetition of some simple act by an individual animal that had occurred immediately before reinforcement. The moment-by-moment modulation of the obtained behavioral atom, both across its emergence in an individual, and across the interreinforcer interval for an individual, was thought to be a very good assay of the effects of reinforcement.

### 2. Subjects / Apparatus / Procedures in Thorndikian Research

#### a. Subjects

##### i. Thorndikian Conditioning with Pigeons

The experimental analysis of behavior is most typically based on the use of pigeons pecking keys that are transilluminated with colored stimuli. The 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. In general, stimulus control occurs and "attentional" factors are not considered an issue. An operant chamber is a relatively featureless sealed enclosure that is just a bit bigger than the subject. As a result, there are few distractions to act as confounds. The behavior is maintained by access to food pellet reinforcers delivered by food magazines under schedules of reinforcement. Food pellets are used as the reinforcer because they are easy and inexpensive to present and remove, they are a "natural" reinforcer, the food is inexpensive and easy to store, and it is straightforward to maintain a constant hunger motivation level without extraordinary procedures.

These choices are not an accident. Every detail of this methodology is the result of decades of optimization. The choices were a maximizing solution 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 best reveals the laws of nature while at the same time is easy to use and is inexpensive.

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. Pigeons have very good color vision. This enables the use of colored stimuli that are easy and inexpensive to produce. Confounding light signals in the environment are easy to control 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.

Key pecking is typically used as the dependent measure because pigeons can engage in it 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 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 typical interest but rather emitted some other behavior. The interest in traditional operant research is in how contingencies affect the behavior they are applied to; not what the animal is thinking nor behaviors that look almost like the behavior the reinforcer followed. The contingencies are applied to only the behavior that operates the key. Typically, only instances of $B_{max}$ are of interest.

Simple stimuli such as red and green light are used because the task is to understand what makes behavior adapt (i.e., short time scale adaptation), not to study the sensory capacity of the organism (i.e., immediate term adaptation). The response is a simple key peck because the task is not to understand how fast or strong the organism is, rather it's to understand adaptation of $B_{max}$ behavior to the contingencies of reinforcement and the simpler the behavior and the more continuously it can be emitted the less likely an idiosyncrasy of the behavior will be a confound. Finally, the reinforcer is simple food pellets because the task is to understand the events that cause adaptation not to understand the food preference of the organism.

### ii. Thorndikian Conditioning with Rats

Rats are the second most popular subjects for Thorndikian basic research. Rats are used for many of the same reasons as pigeons. Their greatest drawbacks are that they do not live very long and as a result can show an age-related change in behavior across long experiments. The typical solution is to not run procedures for very many phases when using rats.

Because rats are not very visual, most often tones, or lights which are either on or off, or left or right are used as stimuli. The typical dependent measure is lever pressing which is the depression of an arm or lever such that a switch is operated. Alternatively, the response measure is a nose poke. In this case, a pigeon key is mounted in a rat chamber and the rat operates the device by pushing it with its nose. The reinforcer used with rats is either small 45 mg pellets which are dropped into a receptacle from which the rat can then eat, or sweetened condensed milk which is made available by raising a small dipper giving the rat access to a controlled volume of the liquid.

Rats are more apt subjects than pigeons if the measure is partially a function of a drug manipulation and if that drug effect will be generalized to humans. This is because rats are mammals and are more likely to react like humans to the drugs. It should be noted however, that to the degree that the drug effect is the focus of the research, the topic is only marginally EAB because the contingencies of reinforcement are not central. The focus of behavior analysis is how the consequence of a behavior affects the behavior. Manipulations such as removing the liver, ablating part of the brain, or administering a drug are seen as research on independent variables other than the consequences of the behavior and of little relevance to determining how a reinforcer affects a behavior.

### b. Apparatus

#### i. Apparatus for Pigeons

A typical pigeon apparatus is shown in Figure 13.12 below.

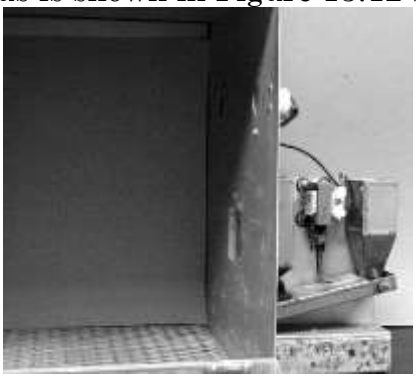


*Figure 13.12 A photograph of an apparatus used to implement typical EAB procedures with pigeons*

Figure 13.13 is a diagram of a typical reinforcement mechanism and the one pictured in 13.12

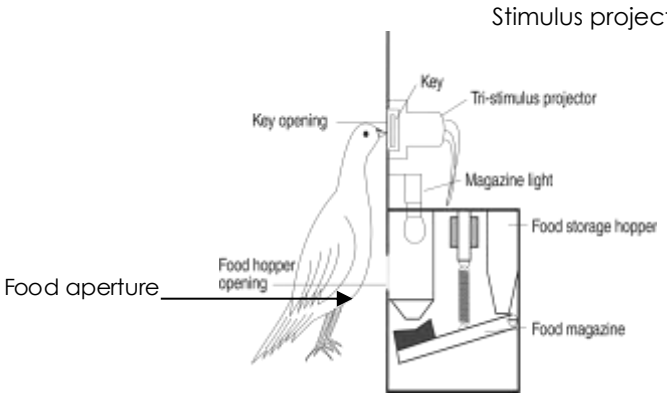



*Figure 13.13 A schematic diagram of a typical apparatus used to implement EAB procedures with pigeons. (Source, xxxx)*

### ii. Apparatus for Rats

A typical rat chamber is shown below in Figure 13.14. As can be seen, the spatial location of visual stimulus is used rather than the hue of a light.

*Figure 13.14 A photograph of an apparatus used to implement typical EAB procedures with rats.*

## c. Procedures

Short time scale organismic adaptation is thought to take place incrementally as the result of increasing experience with the outcome of a behavior. For example, it may take 20 repetitions of a training task or trial to learn a simple task to asymptote and 200 repetitions of a complex task to learn to asymptote. Therefore, the focus of learning research is to come to understand the moment-to-moment adaptation in behavior across repeated exposures to a learning task or "the learning curve." This is often stated by the lay as “how the animal learns” (by which they mean the step-by-step increments in the behavior of the animal).

Schedules of reinforcement are procedures that carefully 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) in bipolar terminology $B_{max}$ at $S^*_{max}$. The types of contingencies standardized in schedules are typically considered the “atoms” from which all behavioral contingencies are built. It is important to note that no one is interested in training pigeon tricks nor in how hard a pigeon will work for food. 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.

The unit of experience with a contingency is labeled a trial when the preparation can be conceptualized as a series of identifiable learning experiences. The term trial in Thorndikian conditioning is used to refer to the period with stimuli leading up to a reinforced response as a historical carryover from discrete trial research when rats ran down an alley to a goal box.

Typically, three pigeons are used in each condition throughout an experiment and are exposed to identical conditions. They are considered as three replications of the procedure. Each pigeon is magazine trained, then shaped to key peck. Subsequently,

each pigeon is exposed to the desired schedule of reinforcement for approximately 30 sessions of 50 exposures to the training task each session. This daily procedure is continued until each pigeon shows no trends in their behavior for 5 consecutive sessions (i.e., the behavior is at asymptote or steady state). As a procedural check and balance, a typical convention is to continue to run all three pigeons until a phase boundary of a multiple of five sessions has been achieved (e.g., 30, 35, 40, or 45 sessions) in order to avoid inadvertently changing phases when the data just so happens to support some particular view at that stage in the experience. The mean within each pigeon for each measure of interest over the last 5 sessions is taken as the measure for that bird for that treatment. Session-to-session data variation at asymptote is considered random noise and is cancelled by using the mean across the 5 sessions for each pigeon. Note that the changes across the 30 sessions are considered relevant information and not simply noise. That change is the moment-to-moment emergence of short time scale adaptation.

The schedule is then changed and the pigeons are run for the next phase of the experiment until steady state. This consecutive changing of the procedure is continued for between 5 and 25 phases each lasting about 30 sessions.

It is generally assumed that prior procedures do not affect the dependent measures of subsequent procedures and that the same results would occur regardless of the ordering of the treatment phases. This assumption is considered warranted in that it has been generally true in the past across a wide array of studies, and data is systematically replicated in subsequent phases and by other research. It should be noted however that carryover effects can occur.

The difference in the behavior obtained in different phases is taken to be the result of the differences in the schedules of reinforcement between those phases (see Figure 1.19,9.5). Any behavior or any property of the behavior can be the dependent variable. The dependent measure is displayed across axes that best reveal the functional relationship of interest. The functional relationships common to all three pigeons are considered the effect, and the similarity across the three pigeons is taken as an index of the generality of the effect across future subjects.

### i. Paradigmatic Measures

#### (a) Validity of Measure Referent

The issue here is the exclusive use of measures that have empirical support or are what has been previously detailed as "understood facts." Prototypical examples would include a key peck but would exclude penis envy.

#### (b) Applicability of Measure Referent

The issue here is well illustrated by the difference between the mean daily response rate within an individual and the mean daily response rate taken across several individuals exposed to the same treatment. The data taken within an individual refers to the change of that **individual** as a result of the treatment; whereas the mean taken across several individuals refers to how the **group** changed as a result of the treatment, and is not relevant to understanding any

individual's behavior. The result on individual behavior could have increased in some, decreased in others, and could have been unchanged in still others. Only If each and every individual shows a particular effect, can it be validly inferred that the treatment resulted in that particular effect. Data determined across individuals is simply not useful in behavior analysis.

### 3. Data in Thorndikian Research: Dependent Measures

Modern computer-based research allows the collection of data with millisecond accuracy. Each event in the chamber can be logged with its time of occurrence and stored as a data element in the record for that experiment. Subsequent analysis software can extract very subtle, but critical functional relationships from the database and display them in a figure so that the functional relationships of interest are characterized by easily perceived changes in space. As a simplistic example, if the rate goes up as a function of time in the interreinforcer interval, then the interreinforcer interval can be displayed across the *x*-axis and the rate can be indicated by the *y*-axis value. In that way, the drawn function depicting the rate will go up as it changes from left to right across the interreinforcer interval. The complexity of the information that can be made to jump out of the figure is limited only by the ingenuity of the researcher.

#### a. Rate of Response

Typical Thorndikian methodology generates a repetitive discrete short duration behavior such as a key peck as its behavioral atom. A key peck is a behavior whose rate can change over a wide range and does not easily fatigue.

The behavior is novel. Therefore, the initial effect of following it with a reinforcer provides a clear assessment of the factors controlling the origin or emergence of short time scale adaptation and is indexed by the initial increase in probability of the behavior as indexed by pecking rate as a function of experience. Additionally, the change in probability of the behavior (again indexed by pecking rate) across the interreinforcer interval at asymptote is an index of the relative change in the effects of the imminence of reinforcement (see Figures 9.21 and 10.20).

The increasing rate of the behavior with increasing experience up to asymptote is an increasing probability of that behavior per unit time, and is often labeled increasing strength and is the typical index of the probability of the behavior or learning. However, it should be noted that fast pecking does not necessarily indicate that the functional relationship is better "learned". For example, the comparison of only the response rate from a DRH and a DRL does not indicate which is better "learned." The focus must remain on correctly assessing the effects of the contingencies of reinforcement on the probability of the reinforced behavior.

##### i. Graphical Display Technology for Depicting Moment-to-Moment Changes in Rate: The Cumulative Record

The cumulative recorder is a device to plot the changes in rate across time. In a

cumulative recording a line parallel with the *x*-axis indicates no responding. a line perpendicular with the *x*-axis indicates infinitely fast responding. This format therefore produces a line whose angle indicates momentary rate. Moment-to-moment changes in rate are easily seen because they are deviations from a straight line. These graphical records are easily created because each response increments the step pen one step on the *y*-axis, while time continuously drives the pen across the *x*-axis. Once the cumulative number of pecks exceeds the maximum-axis value, the pen is reset to the x-axis.

The cumulative record of the behavior of an organism is illustrated in Figure 1315. The figure shows six excursions of the cumulative total responses on the *y*-axis with time on the *x*-axis. In order to save horizontal space, the excursions are shifted left and nested under each other.

The step pen can be piped to represent one event (usually reinforcement) while the event pen, traditionally located along the bottom of the record can only pip and is used to indicate responses to another key or the stimulus conditions in effect so that rate changes can be seen in their context.

The cumulative recorder is rarely used anymore because data stream records can be mathematically processed to extract and directly display any aspect of the moment-to-moment or overall characteristics of an individual's behavior the research wants to observe (see Section VII below). In a sense, proper data analysis and graphical display is to remove the requirement of making a judgement as to what the effect was.

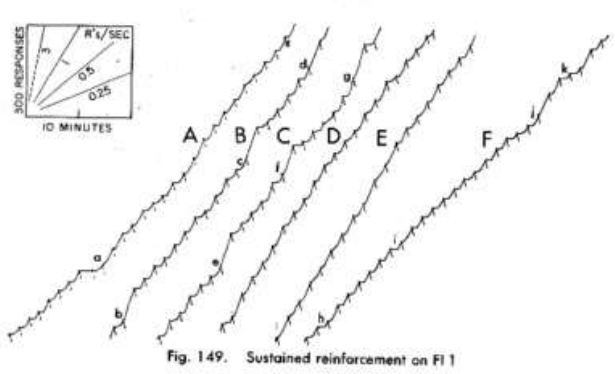


Fig. 149. Sustained reinforcement on FI 1

*Figure 13.15 A cumulative record of a typical EAB session with a pigeon. The diagonal lines labeled A through F depict the cumulative number of responses as a function of time. The six functions are compressed by sliding all the functions to the left thus nesting subsequent functions under the prior function. The key in the upper left indicates the various slopes generated by various mean rates (Ferster & Skinner, 1957).*

### b. Ratio of Different Behaviors

The dependent measure in the case of choice is the relative proportion of two or more alternative responses. This measure is the origin of the lay term “preference” or “choice.”

#### c. Latency

The dependent measure in this case is the time from a stimulus onset to a response. Latency is often taken as an indicator of motivation or even the amount of learning.

#### d. Resistance to Change

##### i. Acquisition

##### ii. Momentum

##### iii. Extinction

#### e. Interresponse Time

A different response metric, which provides different insights, is available to measure behavior. Rather than cumulating responses as a function of time or counting the number of responses in each stimulus, the time between each response could be measured and subsequent analyses and graphics can be based on it.

The time between each response or interresponse time (IRT) can be conceptualized in two ways: first IRT can be a dependent measure each response can be considered its IRT. Many short IRTs indicate a high rate, many long IRTs indicate a low rate, and increasing (decreasing) IRTs indicate a decreasing (increasing) rate. In this way, each individual response becomes the unit of behavior available to be analyzed. Secondly, an IRT can be a controlling stimulus analogous to an independent variable when a response is reinforced, along with arbitrary stimuli, the time since the prior response is the context within which the response is reinforced. For example, the context of a reinforced response could be a key color, if a key peck is regularly reinforced in the presence of green but not red it should be obvious that key color will importantly control the occurrence of the behavior. Just as key color can be an important contextual element, so too is the time since the preceding response, if a key peck is regularly reinforced in the presence of 5 seconds since the preceding response then time since the preceding response will come to control the behavior just as key color.

## B. Schedules to Evaluate Thorndikian Contingencies

### 1. Contingencies to Examine the Role of Response Count and the Passage of Time at $S^*_{max}$

The four basic schedules of reinforcement enforce the conjunction of a response in the context of some number of prior responses or in the context of the passage of time, where the response count or passage of time could be variable or fixed. These conditions are shown in the 2 x 2 contingency table in Figure 13.16

For the response count schedules they are labeled fixed ratio schedule or variable ratio schedule. For the temporal contingencies, they are labeled a fixed interval schedule or a variable interval schedule.

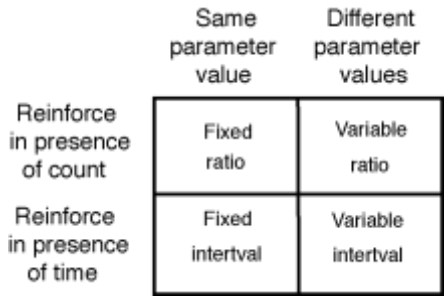



*Figure 13.16 A 2x2 contingency table illustrating the labels for schedules that arrange a correlation between response count or the passage of time and fixed or variable parameter values.*

These forced conjunctions are not arbitrary, rather they are designed to evaluate the role of response factors and temporal factors at the moment of reinforcement on the resulting behavior. A second use for these schedules of reinforcement is that they produce very well-documented behaviors across the imminence of reinforcement gradient, and are used as baselines against which various factors can be assessed.

### a. Glossary of Schedules That Control the Correlations of Properties of $B_{max}$ and $t_{max}$ with $S^*_{max}$

**Fixed Ratio**

A contingency of reinforcement that is designed to ensure that the reinforced response occurs in the presence of a fixed number of prior responses. For example, an FR 50 schedule insures that the reinforced response will always occur in the presence of the stimulus conditions following the 49$^{th}$ response. In a fixed ratio 50 schedule, $S_{max}$ is having pecked 49 times.

**Fixed Interval**

A contingency of reinforcement that is designed to ensure that the reinforced response occurs in the presence of a minimum fixed delay since a marker such as the prior reinforcer. For example, an FI 60-s schedule insures that the reinforced response will always occur in the presence of (or at least no sooner than) the 60$^{th}$ second since the prior reinforcer. In a fixed interval 60 schedule, $S_{max}$ is the passage of 60 seconds.

**Variable Ratio**

A contingency of reinforcement that is designed to ensure that the reinforced response occurs in the presence of any of a number of responses from a distribution. For example, in a VR 20 schedule, the reinforced response may occur after 2, 3 …., 20, …, or 40 responses. The distribution has a specified mean and most typically there is an equal probability that the next response will be reinforced (an exponential or

Fleshler Hoffman distribution). In a variable ratio schedule $S_{max}$ varies from the lowest to the highest count requirement.

**Variable Interval**

A contingency of reinforcement that is designed to ensure that the reinforced response occurs in the presence of any time drawn from a distribution. For example, in a VI 20-s schedule, the reinforced responses may occur after 2, 3, … 20, …, or 40 seconds. The distribution has a specified mean and most typically there is an equal probability that the response following the next time unit will be reinforced (an exponential or Fleshler-Hoffman distribution). In a variable interval schedule $S_{max}$ varies from the lowest to the highest time requirement.

### b. Glossary of Additional Schedules

**Extinction**

This is a procedure during which no operant is explicitly reinforced.

**Fixed Time**

A fixed-time schedule is a response independent procedure that presents food in the context of a fixed passage of time since some marker without a response dependency. Note that the behavior preceding the reinforcer can be any behavior, so the use of the term reinforcement is problematic.

**Variable Time**

A variable time schedule is a response independent procedure that presents food in the context of a variable time period since some marker. The distribution of time has a specified mean and distribution. Most typically there is an equal probability that the food presentation will occur in the next time unit. There is no response dependency. Note that the behavior preceding the food presentation can be any behavior, therefore the use of the term reinforcement is problematic.

**DRL**

A DRL is a contingency of reinforcement designed to ensure that the reinforced response occurs in the presence of a minimum fixed amount of time since the preceding response. A DRL schedule enforces a period of no pecks preceding the reinforced peck. For example, in a DRL 20-s schedule, When the IRT exceeds 20 seconds, the next response is followed by the reinforcer, no peck that occurs after less than 20 seconds is reinforced, thus assuring that no response is reinforced in the presence of any time since the prior response that is less than that specified by the schedule. Note that the reinforcer always occurs following the occurrence of the specified behavior. Note that a fixed-interval procedure enforces a fixed minimum time since some marker. But a fixed interval is different than a DRL because in a fixed interval, any number of responses can occur in the specified interval including a very high rate immediately preceding the reinforcer. In a DRL 20 schedule, $S_{max}$ is the passage of 20 seconds <u>without</u> a peck.

**DRH**

A contingency of reinforcement designed to ensure that the reinforced response occurs in close proximity to the prior response, exactly the opposite of a DRL. The schedule parameter sets the upper limit on the interresponse time gap. Conventional usage permits a number of ways that this contingency could be implemented. For example, any response within 30 milliseconds of the prior response could be reinforced, while any response after a longer delay is not reinforced. Alternatively, a variable number of responses that meet the specified minimum temporal requirement may be required by the contingency. Note that the reinforcer always occurs following the occurrence of the specified behavior.

**DRO**

A contingency of reinforcement that specifies that no reinforcer will follow a particular behavior. The reinforcer cannot happen if the proscribed behavior just occurred. Any other behavior may be reinforced. Because this procedure simply excludes a particular behavior from being reinforced some other specification is necessary to provide when a reinforcer will occur. Most typically a fixed-time schedule is used to schedule the reinforcer. Note that the use of the term reinforcer is problematic in that there is typically no specification of the behavior that will increase in rate as the result of the event said to be a reinforcer.

### c. Classification of Schedules of Reinforcement by Contingency

#### i. Reinforced Response in Context of Constant Value of Single Parameter

- same count since marker (FR)
- same minimum time since marker (FI)
- same minimum time since prior response (DRL)
- same maximum time since prior response (DRH)

#### ii. Reinforced Response in Context of Variable Value of Single Parameter

- multiple counts since marker, specified as the mean of the distribution (VR)
- multiple minimum times since marker, specified as the mean of the distribution (VI)
- multiple minimum times since the previous response, specified as the mean of the distribution (VDRL)
- multiple maximum times since the previous response, specified as the mean of the distribution (VDRH)

#### iii. No Specific Behavior "Reinforced" (Non-Contingent "Reinforcement")

- same time since marker (FT)
- variable time since marker (VT)
- anything but the specified response (DRO)

### 2. Contingencies to Compare the Expression of Different Schedules within the Same Session

At times, research interest is on comparing one procedure with another in terms of their effects on the asymptotic expression of behavior. For example, research could be focused on the difference in the asymptotic behavior controlled by a schedule that enforces a response count as opposed to a schedule that enforces a temporal contingency when the two schedules have roughly the same number of pecks and roughly the same time between reinforcers. The difference in the results would bear on the properties of the two schedules that remained different. The optimum procedure would be to compare the behavior of single organisms under the two schedules when those two schedules occurred in close proximity and were clearly signaled . This analysis could be obtained by concatenating an explicitly signaled exposure to each schedule within the same session. The analytical approach used is to observe and document the equilibrium behavior under one contingency, under one key color, and compare that behavior to the equilibrium behavior maintained by a different contingency under a different key color. It is then assumed that the difference in the contingencies (or chance) caused the difference in the behavior. This procedure of indirectly assessing the expression of short time scale adaptation and was originally illustrated in Figure 1.19.

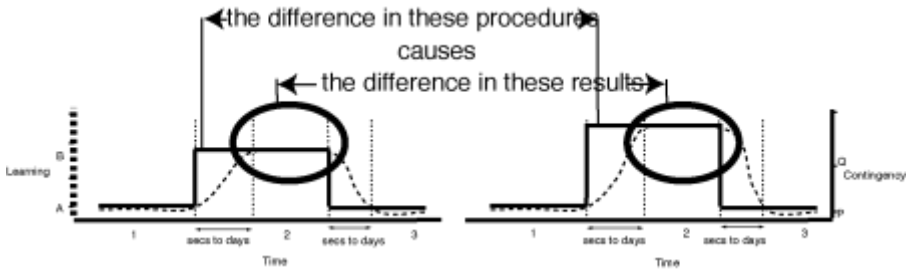



*Figure 13.17 This figure depicts the difference in the asymptotic expression or performance of a dependent variable (dotted line) as a function of a difference in the independent variable (solid line). In sum, the difference in the dependent variable is caused by the difference in the independent variable.*

Figure 13.18 depicts the contingencies in a two-component multiple schedule in a single three dimensional structure . In effect, it is simply combining separate depiction such as those in Figure 9.13 into a single cube in order to emphasize the similarity and differences in the schedules. The two different stimuli on the z-axis depict the two different key stimuli. The reinforced count/time conjunction on the x and y-axis (near side) of the cube, is one schedule (FR), under one hue (green), while the reinforced count/time conjunction on the far side of the cube is the other schedule (FI) under the other hue (red).

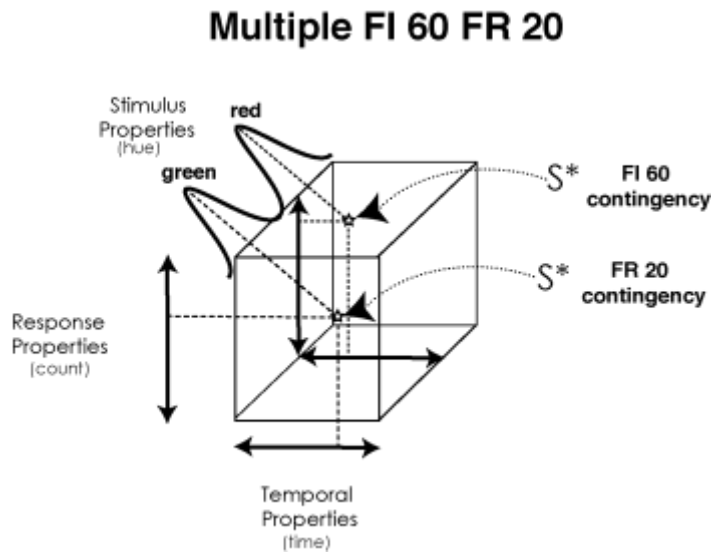



*Figure 13.18 The depiction of reinforcing a behavior under two schedules each designated with its own key color. For example, under a green key light, the response count of 20 is always reinforced (a fixed ratio schedule) and under a red key a least 60 seconds must occur before a response is reinforced (a fixed interval schedule).*

### a. Glossary of Concatenated Schedules of Thorndikian Reinforcement

**Multiple**

A multiple schedule is two or more schedules of reinforcement each occurring only during a distinct explicit stimulus. Typically, one, two, or three trials or reinforcers of Schedule 1 is implemented under one stimulus followed by one, two, or three trials or reinforcers of Schedule 2 under some other stimulus. This is followed by the first schedule again if it is a two-ply multiple schedule, otherwise each of the links is similarly presented until the entire set of links is implemented.

**Mixed**

A mixed schedule is typically but not necessarily a control condition for a multiple schedule. It is exactly the same as a multiple schedule except all procedures are implemented under the same stimulus.

## 3. Contingencies of Reinforcement to Examine the Effect of When the Subsequent Outcome is itself a Schedule

As with all conceptualizations, how these schedules of reinforcement are best conceptualized depends on correctly specifying how the behavior will change with changes in the procedure. The presence of a dominant primary reinforcer at the end of a series of schedules each being without a primary reinforcer can lead to a global effect of the set of contingencies controlling some aspects of the behavior in the individual component local schedules which would not occur in that schedule if it were implemented in isolation. For example, traditionally, serial schedules are

characterized as the subsequent schedule reinforcing the behavior in the preceding schedule of reinforcement. Empirical evidence has not consistently supported that conceptualization. Often a schedule with no "outcome" stimulus supports higher rates in the earlier links than does a schedule containing an "outcome" stimulus (the putative reinforcer) [i.e., technically stated, a tandem schedule can support higher rates than the chain version of the schedule].

### A. Glossary of Serial Schedules of Thorndikian Reinforcement

**Chain**

A chain schedule is two or more schedules of reinforcement where the consequence scheduled by one schedule is entry into the next schedule. Each link is designated by a different distinct explicit stimulus. In sum, each of a series of schedules, each under its own stimulus condition must be completed before the primary reinforcer is presented.

Often, the behavior in a link is said to be reinforced by the stimulus associated with the subsequent schedule. Note that this potential explanation does not enjoy consistent empirical support.

**Tandem**

A tandem schedule is typically but not necessarily a control condition for a chain schedule. It is exactly the same as a chain schedule except all procedures are implemented under the same stimulus. Note that some tandem schedules maintain a higher rate than their comparable chain schedule, thus demonstrating that consecutive stimuli in a chain don't necessarily function as reinforcers. Note however, the data from a chain/tandem comparison is consistent with a bipolar framework

### 4. Summary of Concatenated and Serial Schedules

Traditionally, these procedures are presented with the preceding procedures even though they have quite different mechanisms of action. the following figure presents the four procedures in their familiar contingency table. Note the distinctly different contingencies shown with the bipolar analysis in the subsequent figure

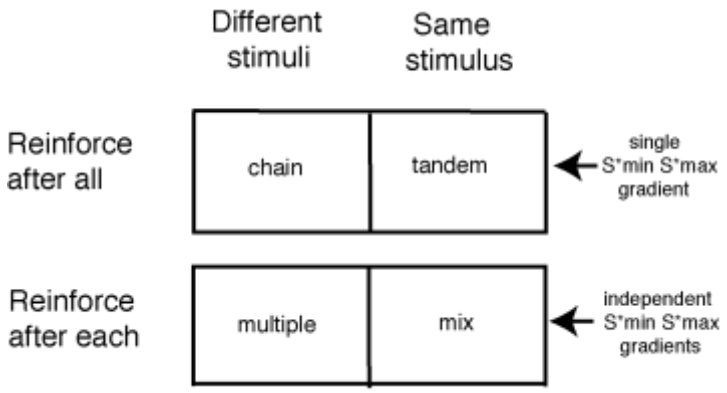


*Figure 13.19 A 2 x 2 contingency table illustrating the basic concatenated procedures used in EAB. Reinforcers can occur after each component schedule or only after all the component schedules are completed and different explicit stimuli can be provided for each component or the same stimulus can be in effect during both components.*

Figure 13.20 better illustrates the distinctly different underlying correlations in the four procedures from the bipolar perspective. Chain and tandem schedules partition a single $S^*_{min}$ - $S^*_{max}$ gradient into two or more components (there is a period with no reinforcer followed by a period with at least one reinforcer). Multiple and mixed schedules are quite different. They are usually characterized by two or more independent $S^*_{min}$ - $S^*_{max}$ gradients because there are reinforcers or $S^*_{max}$ presentations during each component.

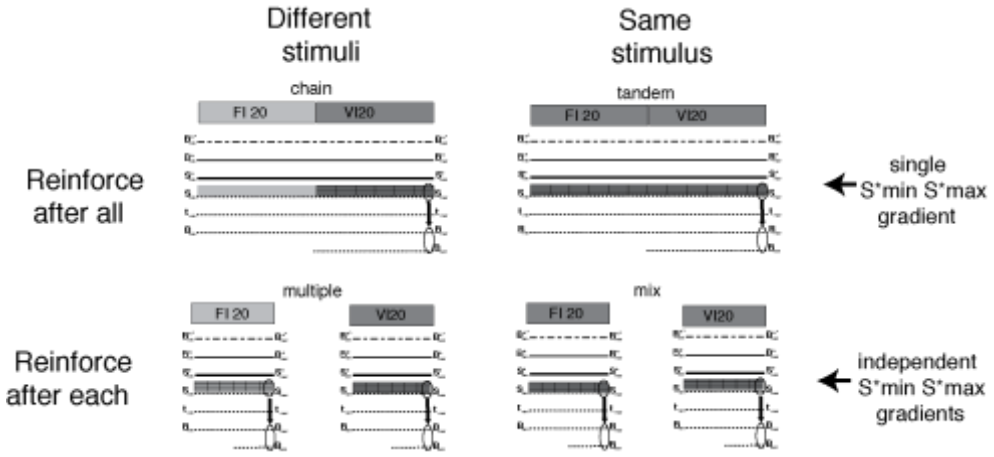



*Figure 13.20 The procedures of the basic concatenated schedules provided in the format first introduced in Figure 10.12.*

### 5. Procedures or Schedules for Evaluating Competing Correlations, or Schedules That Provide Competing Reinforcers for Competing Behaviors

At times, research interest is on why different behaviors occur (often labeled choice). Research on this phenomenon is usually carried out with procedures using two different concurrent behaviors each with its own schedule of reinforcement. In these procedures, at least two different behaviors (e.g., pecks to the left key and pecks to the right key) each have their own reinforcement schedule and the dependent variable is which of the alternative responses occur (i.e., which schedule exerts stronger control and what modulating factors are important to consider).

Each of the following enumerated. concurrent schedules (Figures 13.15 through 13.19) are depicted as distributions of reinforcers "pulling" in opposite directions (because in some ways a concurrent schedule could be thought of that way). One schedule pulls up in the graphic and the other schedule pulls down in the graphic.

The horizontal line with a heavy arrow portrays the passage of time in each figure. The distribution of reinforcers for behavior 1 is drawn along the upper vertical line (it is rotated 90 degrees clockwise). The distribution of reinforcers for behavior 2 is drawn along the lower vertical line and is also rotated 90 degrees. The difference in

the two schedules of reinforcement is illustrated as the difference in the shape of each dotted function. The height of the function above the horizontal line indicates the interreinforcer interval while the height above the vertical line represents the frequency of that interreinforcer interval. This scheme is the typical representation of these factors rotated 90 degrees.

The outcome of the competition between two different schedules of reinforcement is generally that the relationship between the ratio of the two behaviors is the ratio of the two reinforcement rates. For example, if one reinforcer occurs twice as often or is twice as good, then the behavior maintained by that consequence is twice as likely.

### a. Simple Concurrent Schedule

Figure 13.21 provides an example of a simple concurrent VI60-sec VI30-sec schedule. One behavior (behavior 1) (such as key pecks to left) is reinforced on a VI 30-sec schedule, while a different behavior (behavior 2) (such as key pecks to the right) are reinforced on a VI 60-sec schedule. Note that the dotted function for behavior 2 extends further from the horizontal line (i.e., more longer interreinforcer intervals.

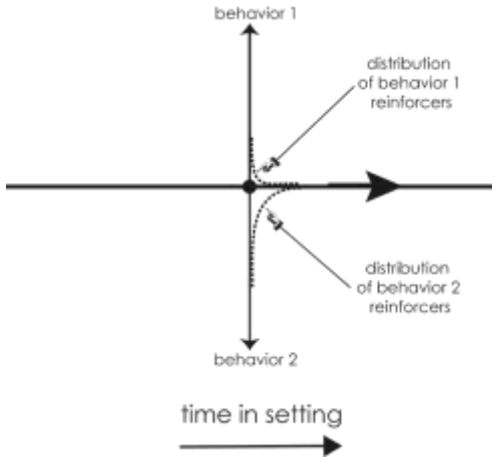



*Figure 13.21 two different responses, each with its own contingencies are shown. Behavior 1 is above the horizontal line. Behavior 2 is below the line.*

### b. Dynamic Concurrent Schedule

In this procedure (see Figure 13.22) the difference between the two concurrent schedules changes. Typically, this change is a function of time. For example, one schedule could change from a VI 480-sec to a VI 15-sec (behavior 2) over the course of five minutes while the other schedule could change from VI 15-sec to VI 480-sec over the same period(behavior 1). As a result, the ratio of the strength of the two schedules systematically changes over the course of the five minutes. The research. interest would be the determination of how the ratio of behaviors tracks the change in the ratio of reinforcers.

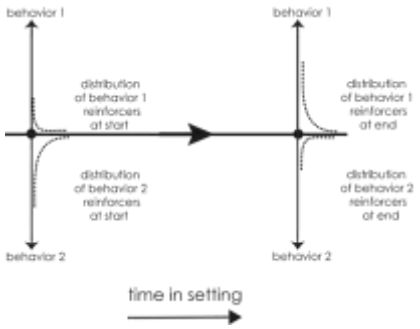



*Figure 13.22 The depiction of a concurrent schedule in which the relationship between the two schedules systematically changes.*

### c. Dynamic Concurrent Schedule with a Shift Cost

In this procedure (see Figure 13.23), the difference between the two concurrent schedules also changes, however in this case, there is a shift cost preceding any reinforcer on the alternate schedule. This is indicated by adding a step between the horizontal line and the vertical line. For example, 25 responses could be required to shift from collecting the reinforcer on one schedule to collecting it on the other schedule.

In these schedules the changeover point systematically changes as a function of the size of the shift cost. For example, when the cost of shifting back and forth between the two schedules is low, frequent changes occur while at high shift costs the difference between the schedules must be large before a shift would occur.

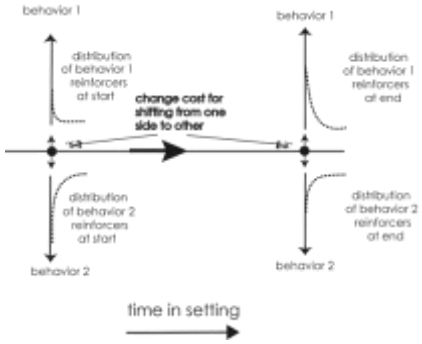



*Figure 13.23 The depiction of a concurrent schedule in which the relationship between the two schedules systematically changes and a switch from one schedule to the other has an initial significant shift cost.*

### d. n Option Concurrent Schedule

In this case, there are more than two schedules simultaneously in effect, four different schedules and four different behaviors are depicted in Figure 13.24 but in principle any number of different responses could be eligible for a reinforcer (note that the fourth vector is labeled behavior n). How the behavior would equilibriate to this type of schedule has not been characterized.

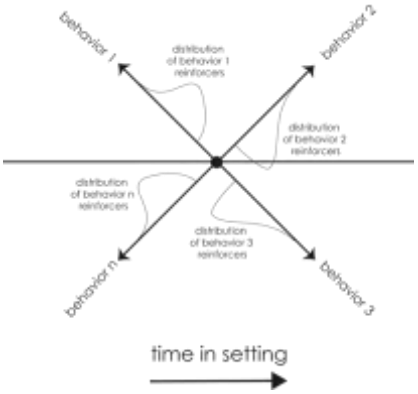



*Figure 13.24 The depiction of an n option concurrent schedule. N different responses are reinforced with n different schedules.*

### e. Concurrent Chains Schedule

In a concurrent chains schedule shown in Figure 13.25, the two outcomes for the two concurrent schedules are schedules of reinforcement themselves rather than primary reinforcers. Typical concurrent schedules assesses the relative pull of two different schedules of reinforcement, ending in the same primary reinforcer and reveal information on the difference in the "pull" of two schedules. A concurrent chains procedure assesses the relative pull of two different outcomes on instances of the same schedule and reveals information about the difference in the "pull" of two subsequent events which are schedules of reinforcement themselves. A concurrent chains procedure is used to measure the relative reinforcing effectiveness of the two-second link schedules rather than the relative reinforcing effectiveness of two schedules of primary reinforcement. The figure shows two identical initial link schedules followed by a leaner (lower portion of figure) and a richer (upper portion of the figure) schedule.

An example of a concurrent chains procedure would be access to identical schedules (VI 60-sec for example). One of those schedules resulting in a VI 30-sec schedule while the other alternative results in a VI-120 second schedule. It would expected that the alternative followed by access to a VI 30 would occur at a higher rate.

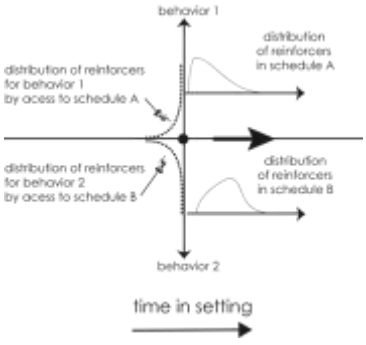



*Figure 13.25 The depiction of a concurrent chains procedure where the scheduled outcome of each schedule is entry into a second link.*

# VII. Practical Experience Doing EAB

### A. The Point or Goal of Analyzing the Data from an Experiment

The object of research in EAB is to understand the functional relationships controlling the moment-to-moment changes in behavior and how those relationships emerge over experience with those contingencies, and change with changes in the stimuli associated with different contingencies.

### B. Example Research

The following research was carried out to examine the control of responding by time in a DRL schedule. The schedule was a DRL 20-sec schedule.

A DRL schedule reinforces the first peck after x seconds (e.g., 20). If the time between every peck is greater than 20 seconds, then every peck is reinforced. If a response occurs before 20 seconds, then the 20 second wait time must start over because reinforcement only occurs in the presence of 20 or more seconds since the previous peck. If pecks occur every 19 seconds, then none will be reinforced.

In this descriptive research example, the asymptotic behavior was assessed. Each of the last 100,000 pecks under a DRL 20-second schedule for an individual pigeon is displayed. (400 sessions at one one-hour session per day). The emergence of that behavior was not included in the figure. Additionally, other parameter values for a DRL (e.g., 10 seconds) and other pigeons or other species were not examined.

In Figures 13.26 and 13.27, the control of behavior by time in a DRL 20-sec schedule is indicated by the density of dots at specific spatial locations representing specific temporal relationships. Many dots in a particular area indicate that there is a high probability of a response at that conjunction of conditions. Few dots in a particular area indicate a low probability of a response at that conjunction of conditions.

#### 1. IRT by Time in Interfood Interval

Figure 13.26 displays the behavior obtained with a DRL 20 schedule. The *y*-axis depicts the time since the preceding peck for each of the 100,000 pecks. It is labeled IRT time. The time since reinforcement or food presentation for each of those same 100,000 pecks is depicted by the dot's position across the *x*-axis.

Sometimes pecks occur immediately after each other (small *y*-axis value dots clustered together in bunches along the bottom of the figure), sometimes the pecks are as much as 30 or more seconds apart (large *y*-axis values dots spread across the top of the figure). Those pecks that occurred immediately after reinforcement (small *x*-axis value) are on the left side of the figure. Those that occurred many seconds after food presentation (large *x*-axis value) are depicted on the right side of the figure.

The origin designates the start of the trial (the termination of food presentation). A first peck after reinforcement which occurs 5 seconds into the interreinforcer interval (IRI), by convention is assigned an IRT of 5 seconds so it is depicted at x=5 y=5, a first peck at 10 seconds is assigned an IRT of 10 seconds, and so on. The IRT

of the first peck since food cannot be less than the time since food presentation, so there are no pecks to the left of the "first peck line" which is the upward diagonal line in the left of the figure. This line is made up of many many first pecks in many many trials. This line has a unit increase, because, by definition, the time between pecks is the same as the time since reinforcement for the first peck in the interreinforcer interval.

All of these first pecks in the trial that exceeded 20 seconds were reinforced and the "dot maker" returned to its home position at the origin. If the number of dots at each position along this line were represented by the height of the line off the paper in a third dimension, then this line would be seen as a Gaussian distribution centering on a *y*-value of 20 seconds. The line would be quite high off the paper at the 20-sec *y*-axis value because roughly half of the 100,000 IRTs exceeded 20 seconds and ended in a reinforcer and caused a return of the dot marker to the origin.

The other half of the pecks had an IRT of less than 20 seconds and therefore failed to result in food presentation. In that case, the dot maker dropped down to the *x*-axis because the time since the prior peck = 0 (*y*-axis value =0) but the time since food is still some positive value. A new IRT started, but the dot did not reset back to the y-axis (time since food not = 0) because the interreinforcer interval did not restart because the peck had failed to meet the DRL contingency. As the time continues to elapse, the IRT and IRI continue to elapse and the dot maker position rises at the same unit diagonal as the first peck line (its origin however is the IRI time that that first peck had occurred.)

The second diagonal line is wider than the first peck line because its point of origin varies as a function of the variation in the time of occurrence of the first peck that failed to exceed 20 seconds (i.e., 1-19 seconds).

The cluster of pecks just short of 20 seconds on the *x*-axis along the bottom of the figure (i.e., small *y* values) indicates a cluster of short IRT pecks following the first peck in the IRI that was just a bit shorter than the 20-second IRT criterion. For example, a peck at 15 seconds since food which dropped the dot maker off the first peck line back to the *x*-axis followed by a peck one second later would put a dot at 16 seconds on the *x*-axis and at 1 second on the y-axis. If this were followed by a peck 22 seconds later, it would be depicted by a dot at 38 seconds on the *x*-axis and 22 seconds on the *y*-axis. The dot makes would then return to the origin because the 20-seond criterion for reinforcement had been exceeded. On the other hand, if the peck had occurred 19 seconds later, it would have been depicted by a dot at 35 seconds on the *x*-axis and 19 seconds on the y-axis. This process continues in some cases for four or more "almost-20-second- IRTs" in a row, each diagonal line being wider than the one before because the variation of each successive peck is added to the variation in the time of occurrence for all preceding pecks.

Probably the easiest and quickest way to "see the dolphin" in Figure 13.31 is to place your finger on the origin and imagine a pigeon immediately after reinforcement standing there looking around not pecking. As time elapses, slide you finger up the diagonal that represents 1 second since the last peck and 1 second since food presentation, then 2 since last peck and 2 since food presentation, then 3 and 3; 4 and 4 and so on. You can choose to peck before the 20 seconds specified by the DRL schedule (e.g., 10,10) or after the 20 seconds elapse (e.g., 24,24). Suppose you wait for

25 seconds to peck (at that time your finger will be at 25 and 25). Imagine that a dot is placed there to represent that peck. That peck would be reinforced so you reset your finger back to 0 seconds from the last peck and 0 seconds since food presentation (i.e., the origin). Repeat that exact behavior three times to represent 3 pecks exceeding 20 seconds that were reinforced with a dot placed on the first peck line at each time the peck occurred. On the fourth trial, peck at 18,18. Place a dot there. That peck will not be reinforced so you do not go back to x=0 but rather drop straight down to 18 on the x-axis and zero on the y-axis. Imagine a second peck after only a second. A dot would then be placed at x=19, y=1 which drops your finger to x=19, y=0). Now imagine the pigeon again goes back into waiting. Now your finger travels up the diagonal to 20,1; 21,2; 22,3; and so on. It is exactly parallel to the first diagonal but displaced 19 seconds to the right. Suppose the pigeon waits 22 seconds. A dot would be placed at 41,22. The peck would be reinforced and the finger would go back to zero, zero. Variations of this pattern are repeated 100,000 times in Figure 13.31.

The diagonals at approximately every 20 seconds across the *x*-axis depict how many times the pigeon missed the 20-second requirement in a row. The little cluster of pecks just before 20, 40, and 60 seconds at low y-axis values depicts second pecks immediately following a peck that had just missed the 20-second DRL requirement.

The thin line dropping from "30" down to about 2 from left to right is a "survivor" function and depicts how many of the 100,0000 responses have not occurred by each interreinforcer interval on the *x*-axis. The axis for this survivor function is 100% at the *y* -axis label of 30 and is 1% at the *y*-axis value of 2.

Further analysis reveals additional interesting details about DRL behavior.

### 2. IRTn x IRTn-1

In Figure 13.27, the x-axis is the IRT of the peck preceding the one represented by the y-axis value of the dot. In that way, the figure displays how the "present" IRT value is governed by the value of the duration of the preceding peck rather than how it is governed by the time since food presentation as was portrayed in Figure 13.26.

In overview, all pecks higher than 20 on the y-axis were reinforced because they exceeded the 20-sec criterion of the DRL 20, just as they were in Figure 13.31. In this case (Figure 13.32), the x-axis provides information about the IRT preceding the designed IRT. All pecks to the right of 20 on the x-axis had been preceded by a reinforced peck and are therefore timed since the end of reinforcement rather than since the previous key peck.

The large cluster of dots centering on $x$=20, $y$=20 indicate pecks that were close to the 20-second requirement two times in a row. The apparent upward shift in the right half of the cluster at $x$ =20 to longer IRTs occurs when the prior IRT exceeded 20 seconds. This would indicate that when timed since food presentation rather than a previous peck, the distribution of IRTs is slightly longer.

Again, further analysis of the figure reveals additional details about DRL behavior.

Figure 13.26

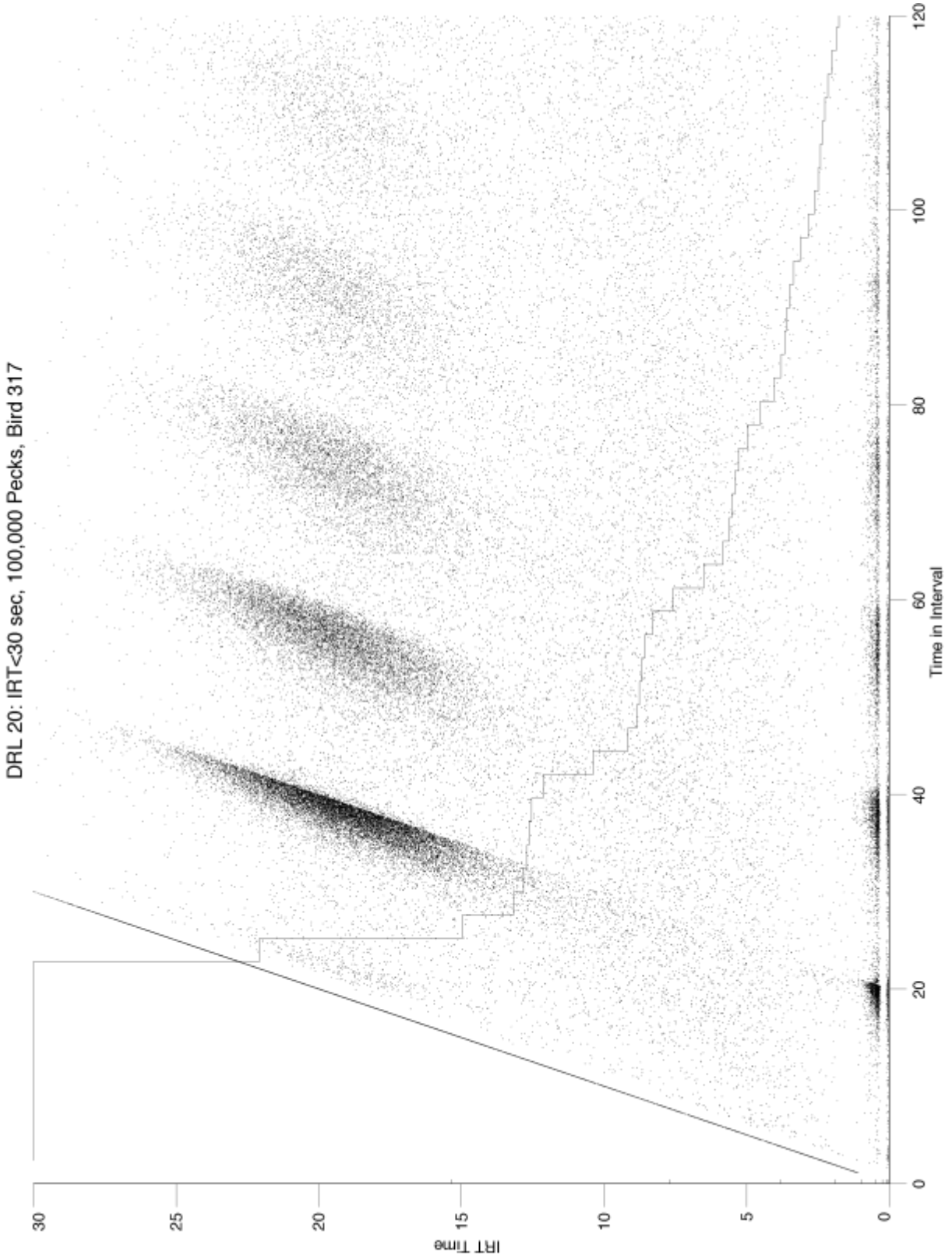
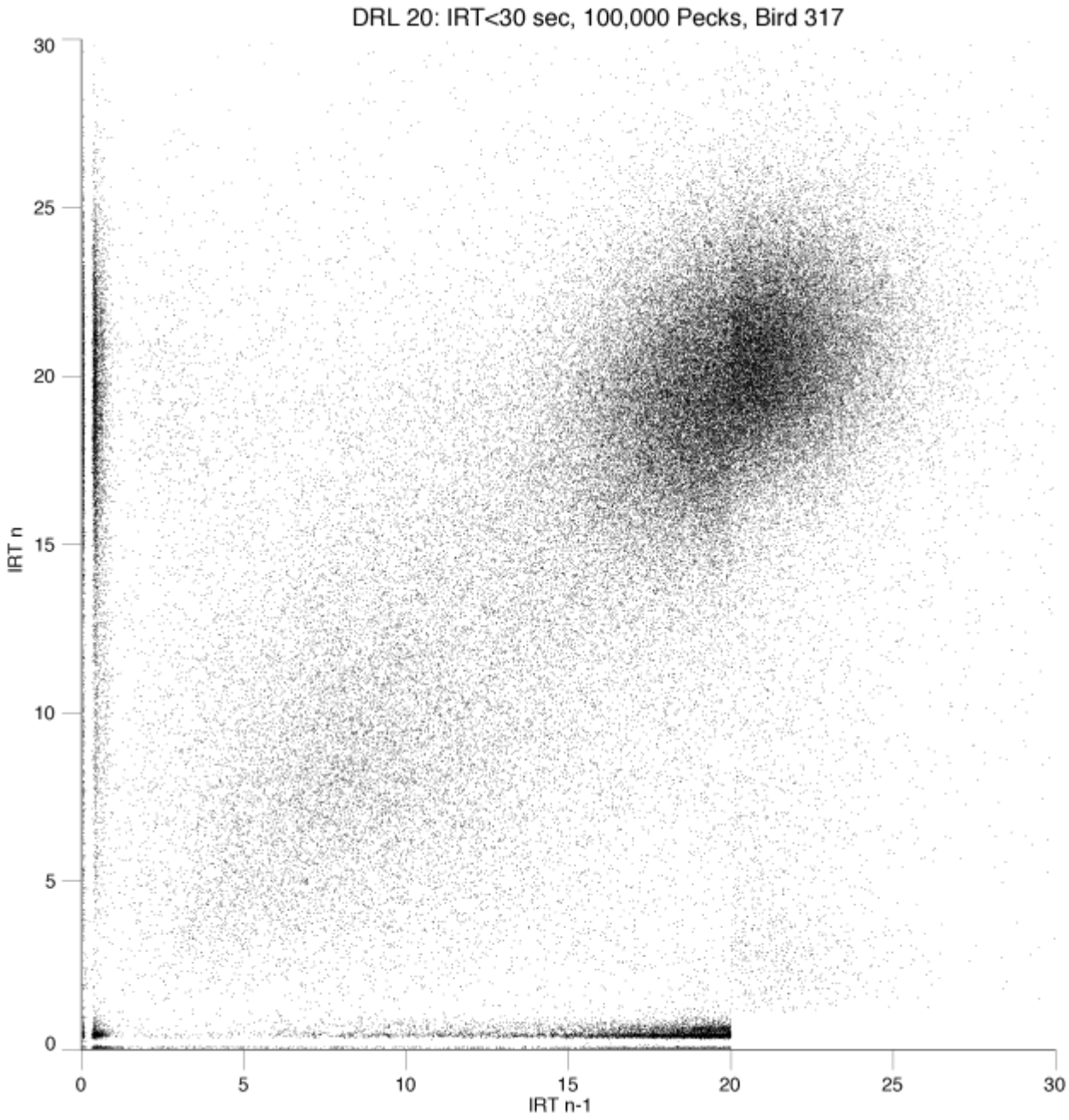

DRL 20: IRT<30 sec, 100,000 Pecks, Bird 317
IRT Time
30
25
20
15
10
5
0
0
20
40
60
80
100
120
Time in Interval

Figure 13.27


DRL 20: IRT<30 sec, 100,000 Pecks, Bird 317
IRT n
IRT n-1
0
5
10
15
20
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30