## **CHAPTER 8**

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Chapter 8 - CF

## **CHAPTER 8**

# The Contribution of Knowledge to the Field of Psychology

A discipline advances because people like you have a better idea than the existing body of knowledge. Adding understanding to the field of psychology is both exciting and gratifying. The process of generating knowledge can be seen as asking why or having a perplexity, and then doing something to answer it.

One of the most exciting things about science is its infinite supply of questions. There are as many research questions left as there are songs or novels left - and for the same reason, it all depends on your ingenuity. There are more than enough great discoveries for everybody. On top of that, all of humanity may be better off because you chose to answer your question. The next time you confront a problem and have an idea which may solve it, do it!

## I. Why Perform Experiments

#### A. Because it Produces Knowledge

Knowledge is understanding covariance. It allow you to help others and help yourself by knowing what goes with what.

#### B. Because it is Fun

It is so much fun, many researchers talk about doing research as a socially beneficial addiction. A frequently quoted, humorous aphorism says it all, "don't discover if you wanna recover." There are three aspects of doing research that makes it fun.

#### 1. Indulge Curiosity

It's intrinsically fun to explore or discover. It's what drove Columbus west. It's what compels children to take apart toys to see how they work. It's what compels scientists to take apart the universe to see how it works.

#### 2. Challenge

Rising to a challenge is what makes us have pride in ourselves and it's what makes us grow. Crossword puzzles are fun because they are hard not because they are easy and have obvious solutions.

#### 3. Social Reinforcers

When we discover something, we gain knowledge that other people do not have. We then have the opportunity to give them something that they want. This ability to give people what they want or need is the motivation which underlies the joy of Christmas.

## II. Sources of Problems to Solve

Problems can be conceptualized at a number of levels. At one level we are all searching for the answer to the question "why do organisms behave the way they do?" Questions with more specificity could proceed from; why do humans behave the way they do, to how does reinforcement affect behavior, to how does reinforcement affect studying, to how does reinforcement affect studying for tests in university males.

Beginners tend to start with relatively specific research problems focused on the face value of the question, but eventually develop a broad research question with great generality. For example, what started as "how can I help my roommate study more?" evolves into "what controls studying in people?" to "what controls the behavior of organisms?" At the beginning, the roommate's behavior is at issue for itself. Later the person and the behavior are seen as arbitrary instances of a much more important and challenging question. Career long research problems tend to emerge following several years of specific research topics, and those research programs require many specific research studies to solve. This section details some of the sources for an initial, relatively specific, research problem. It is intended to help you come up with research which is manageable, enjoyable, and productive.

A very serious impediment facing new researchers is well illustrated by trying to use a foreign language dictionary to learn what foreign words mean. Until you know enough of a language, you cannot find out what the words mean. Until you know enough of a paradigm, you do not know what unresolved questions remain, or when the paradigm is wrong. "A" below is generally a person's first exposure to a research project for that reason.

In addition to not knowing what unresolved problems remain, beginners often do not see the more fundamental broader issue underlying any specific behavior change. When a beginner looks at the world, the challenge is to see each functional relationship as only an instance of a more general class of relationships.

#### A. Research Problem from Expert

The simplest source of a problem to solve is to have it given to you; as a class assignment, as a directed research project, or as a task while you are an apprentice in someone's lab. You are told what problem to research and how to do it. This is probably an ideal way to assure that your first research topic is a good question which leads to a useful answer.

Example: Students in Experimental Psychology were assigned the task of finding out if social attention made their roommate study more. They were told to measure the amount of time their roommate studied on days during which they expressed interest in their roommate's course material as compared to days when they refrained from talking about academic topics.

#### B. Research Problem from Folklore

Common beliefs, common sense, or proverbs could be right but on the other hand, they could also be wrong. It is possible that some unverified beliefs have the roots of a better idea and therefore would be a worthy research topic. However, you must verify that they are true before considering them as a source of knowledge. It is critical to realize that the task of research is not to simply validate or invalidate common sense but rather to come to understand nature.

Example: It's commonly believed that studying within the two hours preceding a test will decrease test scores. To research this belief a randomly selected half of a class was told to study immediately before taking a test while the other half was prohibited from studying before the test. This research was intended to determine whether or not studying immediately before a test decreased the points earned.

#### C. Research Problem From Insight

Sometimes people research an issue simply because it occurred to them and it seemed important. The systematic development of the idea is lacking. This is "intuitive" or good guess research. It is risky because you may not be able to get other researchers to understand why the research is important. It is fun because you get to do what interests you at the moment.

Alternatively, this rationale for research could be the application of a general rule of thumb or even guessing that a new problem is nothing more than a wellunderstood function in disguise.

Example: While feeling especially competent after explaining course material to three friends you realize that orally presenting material may help test performance. You conducted a study in which the subjects orally presented material before the test on a random half of the occasions. The research was based on your insightful realization that oral presentation may increase test performance.

#### D. Research Problem from Informal Discussion

This is a research problem that some discussion group feels is interesting. Discussion among friends can often spark our interest in a problem or provide us with the reinforcers for pursuing a question.

Example: After telling a group of friends about your success with oral presentations on test taking, the group talks about it for awhile and becomes interested in the possibility of the subject becoming confused as well as doing better as the result of feedback from the listeners. The group provides you with the idea and the excitement to do research on how students can affect the accuracy of a teacher's understanding.

#### E. Research Problem from Knowledge of Techniques and Apparatus

This is the selection of a research topic based on your special knowledge outside the field. A technique or apparatus with which you are familiar can offer the potential for a major advance in the field of psychology. Sometimes we realize that we can apply a new technique or apparatus to an area to which it has not yet been applied. Because it is a person's unique skills or knowledge that has led to success, solving the problem can be especially gratifying.

Example: You may know about microelectronics and be good at detailed work. You find out that many researchers are anxious to discover the migration patterns of butterflies so you mount an integrated circuit transmitter on a butterfly and thereby trace the behavior of the free ranging butterfly.

#### F. Research Problem from Reading the Literature

These are research problems which capture your interest while reading. While reading you will often wonder why, or will disagree, or will realize that you have a better idea than the original author.

Example: While you were reading about jet lag and its effects on sleep the first night, you realize that the author failed to control for light cycle. You try stretching either the light period or stretching the dark period to make up the phase shift. You implement this by changing the cabin illumination period on various trans-Atlantic flights, and monitoring the passengers sleep for the next three days.

#### 1. Sources of Research Literature

Initially, it may be hard to know where to start reading on your quest for

knowledge. Consider starting at a very broad general level and working your way to the more recondite.

A good place to start is skimming through several Introductory Psychology textbooks to understand your research question at the broadest possible level. Understand the basic area, what it is, how it fits in Psychology, and why it is important. Then look through several middle level textbooks which cover that particular area. It is easy to understand the structure of the area by reading the Table of Contents; you can then read the specific section relevant to your research topic. Read the Table of Contents and sections relevant to your paper in several more textbooks, paying particular attention to the original research which led to the general paradigm and conclusions. Pay attention to the theoretical significance of various types of results and to the functional relationship depicted in the figures. Middle level textbooks will reference several critical original papers directly relevant to your research question as well as discussing why they are important papers.

In order to broaden your knowledge base in the specific area of your research question, Note the authors, titles, dates, volume, and pages of the journals and books which are referred to in those papers. Additionally, use web-based abstract search engines such as PsycINFO. Alternatively, consult Psychological Abstracts which is available in the library. These sources provide short abstracts of the mass of knowledge provided in journals. Locate key papers which provide information bearing on your research question in the Abstracts.

To review your search algorithm:

Introductory texts Second-level or area texts Annual Review / review articles Special topic text / symposium reports Journal articles

#### 2. How to Find Additional Sources

Web search
PsycINFO
Encyclopedia of Psychology (http://www.psychology.org)
Card catalog
Psychological Abstracts
Current Contents
Citation Index (find subsequently-published related articles)
Reference sections of relevant papers (find previously-published related articles)
Knowledgeable people

## 3. How to Read Research Articles

Actively participate while you are reading. At first it will keep you from falling asleep, later it will keep you from thinking about other things, and eventually it will make it a lot of fun.

Underline important ideas, write questions and answers in the margins, and keep an idea log. Draw a diagram of the procedure.

Consider how the research bears on your interests.

Look for what's important.

What was the research problem and why must it be answered?

What subjects were used and why?

What apparatus or setting was used and why?

What general procedure was used and why?

Was the procedure applicable and the best available?

What was the independent variable, how was it measured, and what was it inferred to be doing (its interpretation) (e.g., did shock produce fear or something else)?

What were potential confounds and how were they controlled?

- What was the dependent variable, how was it measured, and what was it inferred to be the result of, or what did it represent (its interpretation)?
- What were the empirical results, what were they interpreted to mean, and to what extent is it likely they would happen again if the experiment were replicated (their reliability)?
- How sensitive was the dependent measure? To what degree would small changes in the independent variable be expected to change the dependent variable?

How much of the variability obtained could be accounted for?

- To what extent will the findings apply to other subjects, situations, and procedures? Was there generality?
- What was gained by the research ("so what")? How has the paradigm been extended by this finding?

## G. Research Problem from a Paradoxical Incident or Conflicting Results

If the world is perfectly understood, then there can be no surprises. Contrariwise, if something surprises you, then your theoretical framework is inadequate and needs development. If two seemingly similar procedures produce different results, then something is wrong with your understanding of the procedures. They are not actually similar in the important respect of how they affect the dependent variable. Given that a misunderstanding has occurred, something is not correctly understood and the discrepancy must be resolved.

## H. Research Problem Deduced from Paradigms or Theories

Researchers who propose theoretical accounts for phenomena cannot think

through every possible ramification. As you come to understand a theory, potential errors or extensions become apparent. This type of research tests the implications of theories to confirm or reject them. This is classic deductive "normal" science. Using the object in the lake from the first chapter as an example -- this would be deducing "if it is a steam shovel under there, then we should find a long row of high spots coming out of one end." You then test that prediction by probing around trying to find a boom.

If response strength approaches asymptotic response strength on each reinforced trial, then presenting a compound stimulus of asymptotically conditioned stimuli should result in a response decrement on subsequent tests with isolated stimuli. (This is a counter intuitive prediction based on the Rescorla-Wagner model of learning which turned out to be true.)

## III. Activities Which Solve Problems and Produce Better Knowledge

Once you have a general understanding of why to perform experiments and a topic you want to understand you can usually go forward. But sometimes it's hard to decide exactly what activities to engage in, or how to conceptualize the kinds of things you might do in that research area. Often we say we do research in order to discover new information or discover the cause of something or even simply to answer why. Unfortunately these goals don't give beginners much of a handle on what to actually do. If you have difficulty knowing where to start, your research question may be too global for a beginning. Start with a very specific subset, one which will help you understand the big picture but may not solve it all at once. At its most specific a research question is simply a specific research activity. But generally a research problem is more general and could be solved by any of a number of activities. A general approach to help you get started, therefore, may be to not start with "how can I solve the problems of the world?" Rather, start with how can I help my roommate study more? Then think of the more general issue of what factors influence studying? Then eventually, why does behavior work the way it does? The answer to this final, most general statement of the specific question is pretty close to "how can I solve the problems of the world?"

#### A. What if ... / Indulgence of Curiosity

This activity is perfectly acceptable research. Simply do what seems like an interesting manipulation. Your background lead you to wonder what would happen if you did it, other people may have the same question. In fact many important scientific discoveries were made because the researcher did exactly

that, "I wonder what would happen if I do ....." The risk in this type of activity is that your manipulation may have already been studied or no one else may be interested in your question.

Example: Building on the social attention example, you might want to know what would happen if your roommate were exposed to several people interested in their course material.

#### B. Verification, Replication and Systematic Replication

Some findings have only been demonstrated once. The original study could have been flawed. It is important that our knowledge base be on better grounds than a single demonstration. This type of research (i.e., verification) is one of the factors that enables science to be self-correcting.

#### 1. Direct Replication

Example: Do an experiment over. Do everything exactly the same as the original.

#### 2. Systematic Replication

Change the subject, apparatus, or procedure in order to obtain a slightly different perspective or slightly extend the research. In this case, you maintain the same process thought to be the causal factor (i.e., reinforcement), but you freely change whatever is thought to be an "irrelevant" specific factor (e.g., food as the reinforcer). For example, if it was the consequence that got the pigeon to peck the key (food reinforcement), then you should be able to get your roommate to study with a smile or some other reinforcer.

#### C. Improving Measurement

Many pioneering research studies did not use what have become the best measures for the independent and dependent variable. Better research measures the behavior more directly rather than indirectly, and measures it more accurately. Additional improvement can be obtained by moving up from a nominal, ordinal, or interval, to a ratio scale.

Example: You refine the "interest" measure of the people talking to your roommate into those which simply show interest, those which ask for a fact, and those which ask for some integration of information. You then compare the effectiveness of each.

#### D. Unconfounding

Occasionally research is published with an unobserved confound which you

may notice. The study can be redone without the confound.

Example: You read an article which manipulated a variable intended to increase exploration in rats (it failed). You realize that it was conducted during the day when rats normally sleep. You redo the experiment and run it during the dark part of the rat's light cycle.

#### E. Specialization

General functional relationships may or may not apply to specific situations. Measure what is proposed to be a general effect in a particular group.

Example: The effectiveness of social attention on studying behavior was examined in students from lower socioeconomic status families.

#### F. Generalization

Functional relationships obtained in a specific situation may or may not generalize to other situations or populations. Measure behavior in other groups or other situations.

Example: The effectiveness of social attention on reading the instruction manuals which accompany VCRs was tested with a variety of people to see if social attention affects behaviors of people with various educational levels.

#### G. Technological Advancement

A technological advance in one discipline may have an enormous impact on the production of knowledge in another discipline. New tools may reveal the answer to long standing questions. If you have a particular research problem already chosen and you can bring new technology to bear on it - do it.

Example: Visitors at a zoo were monitored while near instruction signs using a TV camera with a telescopic lens. The effectiveness of other people asking questions on increasing reading was assessed.

#### H. Recombination

Sometimes the information we need is the synthesis of two or more previous functional relationships. The combination of two different research designs can provide a simple and elegant demonstration of a complex functional relationship.

Example: A 3x3 factorial design was used to manipulate educational level and previous experience with social attention on the amount of studying that occurred.

#### I. Establishing the Existence of a New Phenomenon

You may be interested in demonstrating some new functional relationship. In

this case you would change your procedures around until you have a clear demonstration.

Example: You believe that the effectiveness of social attention is determined by specific experiences in life before the age of two. You find groups which react differently to social attention and examine their infancy. You also sort infants into two groups according to your criterion experiences and follow up their susceptibility to social attention over the next thirty years.

## J. Testing Prediction from Theory

The validity of a theory is assessed by generating a prediction based on the theory and then testing to determine if the theory was correct. This is classical deductive research.

Example: Your theory predicts that this early determinant of susceptibility to social attention also affects the person's verbal skills. You compare GRE verbal scores of the two groups known to differ with respect to early experiences.

## K. Construction of Functional Context

This type of research is forced when an unexpected behavioral relationship is uncovered. The existing theoretical formulations do not handle the result and, therefore, a functional context for it must be established.

Example: You find that once someone begins to obtain reinforcers from one person regularly, other people do not function as reinforcers as well, you then track down the experiences that make the effect worse and which lessen or remove the effect. You also try to find other instances of a similar effect.

## L. Integration of Finding into an Existing Coherent Framework

The identification of the "underlying cause" of a psychological phenomenon can be the goal of research. You may know of a particular functional relationship and be interested in discovering exactly why it works the way it does. This is classical inductive research.

Example: Continuing the above research, you develop a model which predicts the types of experiences which potentiate or retard the effect and you determine the ontogenetic or phylogenic processes of which the particular effect is an example.

## IV. The Process of Discovery

#### A. Research Strategy

Research can be "top down" or "bottom up." You can have a general view of how things work and want to expand or test that paradigm. Alternatively, you may see a behavior and wonder why it works the way it does. Research can be classified in terms of these strategic approaches. As a result, there are two major classes of systematic research. Each class generates knowledge by using a different logical approach, or by "coming at it from a different direction."

#### 1. Deductive Research

This class of systematic research begins from some knowledge base, attempts to extend that knowledge base by making a prediction, and then verifies that extension by comparing obtained empirical results to the prediction. Alternatively, you may think a theoretical explanatory system has a flaw because you think behavior is the result of some other process. In this case, discovery is made by specifically designing research to provide some result which is inconsistent with the predictions of the existing theory while being consistent with the new theory. In this regard the actual experimental procedure and results have no intrinsic interest other than to support one set of principles while falsifying some other set. Nobody cares that the pigeon pecks a blue key more slowly on a VI 240-sec than when on a VI 60-sec schedule. Whether it is a pigeon or a human being; whether it is a blue light or a yellow light; and whether it is a VI or an FR are all seen as irrelevant. What researchers care about is that behavior is a function of reinforcement rate, and that decreased reinforcement rate decreases the probability of the behavior which it supports.

#### a. Discovery Via Premeditated Design

#### i. Comparison of Results to an A Priori Prediction

In this subset of deductive research the study is specifically designed with the intent to compare some aspect of the results with what was predicted to happen. For example, if the pigeon pecks the left key, one theory is supported; if it pecks the right key, then some other theory is supported. This is the prototypical "hypothesis testing scientific method" presented in textbooks. It is important that you clearly understand the theory and clearly think through the various possible results before doing this type of research. The value of this type of research is entirely dependent on the quality of the design. The first issue is that the existing theory can have no way of explaining the obtained behavior if the research will be used to falsify the existing theory. Secondly and ideally there can be only one reason for the behavior to occur as it did, otherwise the results do not necessarily point future theorizing in some direction. Finally, the best designs

enable something productive to be said no matter what results occur. Always spend enough time designing your research procedure so that you will have something positive to say no matter what happens. For example, pecks to the right support one theory, pecks to the left support the alternative theory, while no pecks support a third theory. Doing research in this way is a very powerful methodology because the results always bear on the paradigm. You will be able to publish the results no matter what happens. In a sense, "negative" results simply mean that the researcher didn't plan ahead. Well planned experimental designs are a necessary methodology for dissertations because it won't leave you "snookered."

#### (a) Based on Intuition

That deductive prediction can be based on your intuition, e.g., "I don't know why, but I'll bet the subjects will do xxx if the environment changes to yyy." We often have knowledge we can't clearly articulate (which is perfectly OK). When our intuition is at variance with accepted knowledge, however, we must do research to either better the field or better ourselves.

#### (b) Based on Theory

That deductive prediction can be based on a theory which predicts a relationship, e.g., "if deprivation is increased then the rate will increase."

#### (c) Based on Model (quantitative theory)

That deductive prediction can be based on a model which specifies an exact quantitative value, e.g., "if reinforcement rate on x is decreased by one-half then response rate on y should increase by one-third. This type of quantitative theorizing and testing is of growing importance and is the future of psychology.

#### ii. Post Hoc Realization of Functional Relationship

Very often data are generated in an experiment which had been specifically designed to only reveal a particular phenomenon, but those data provide information in addition to simply supporting or refuting a specific deductive prediction. Functional relationships other than those of our original interest may be discovered in the data from a design premeditated to simply evaluate a prediction. We should make the most of the work we put into doing research by getting every possible piece of information out of it. The more analytical effort this activity requires, the more this aspect of deductive research becomes inductive research.

### 2. Inductive Research

This second research approach, or philosophy, begins from some observational or experimental result and attempts to integrate the finding within some theoretical context. Whereas deductive research starts with theory and implements a behavioral test, inductive research starts with a behavior of interest and searches for an integrated context.

Interesting or surprising results are usually those for which our explicit or implicit paradigm did not prepare us. Therefore our interest in some particular functional relationship may, at the bottom, actually, be the result of its support or refutation of some implicit paradigmatic expectation. As a result the separation between deductive and inductive research can sometimes be a bit fuzzy, but in general, if you observe some behavior and wonder why, then you are doing inductive research.

## a. Discovery Via Post Hoc Organization of Data i. Comparison of Results to Known Functions

This is reorganization, rearrangement, and restructuring of data in order to determine whether or not it matches well known or predictable relationships. This type of "playing" with the data has particular regularities in mind. You analyze your data looking for specific functions. These attempted solutions could be generated by theories, models, or even intuition as is the starting point in deductive research.

## ii. Description of Functional Relationship

Very often things happen in an experiment for which you have no preexisting knowledge and no particular "ax to grind." Functional relationships other than those previously documented may be observed. In this case your primary task is one of accurately and completely describing a phenomenon whose larger context and set of controlling factors you can only guess. The next step in the research program would be the construction of a broadly based functional context (see below).

## (a) Speculation

We can have a hunch about the ultimate nature of the functional relationship and analyze and display our results to best point toward that speculative function.

#### (b) Eventuating in a Theory

We may be able to formalize our intuition into a general theoretical model which makes clear, qualitative predictions and is falsifiable.

## (c) Eventuating in a Model (Quantitative Theory)

We may be able to formulate a quantitative model of the obtained functional relationship and wish to argue that that model is applicable in other situations.

#### b. Discovery Via Construction of Functional Context

This general class of inductive research, not only reorganizes data to see what's there, but also carries out specific experimental procedures in order to better characterize the phenomenon of interest. It goes beyond a simple description of the functional relationship by carrying out research that enables the specification of how the function changes with changes in procedures, and attempts to integrate the phenomenon into a broad context.

#### B. Research Design

Unless you have perfect knowledge, you must gain valid knowledge about phenomena of interest. Research is required in order to understand what happens, why and when things will happen, and how to alter the normal course of events. Without complete knowledge, you must gather information, interpret the results, and make a decision.

If you are taking either a deductive or inductive approach, you must design your research to maximize your likelihood of arriving at useful information. This requires that you exclude both confounds and chance as plausible explanations for your results. Otherwise, you will have nothing credible to offer the research community.

#### 1. Conceptual Precursor

#### a. Difference Measures to Cancel Confounds

In simple language, an experiment is a method of exposing and understanding the cause of an effect. It must be remembered, however, that any candidate is not necessarily the true cause, and you are in search of the actual cause. Rarely will you ever be in a situation where you see nothing but the relationship between some very specific isolated, causal input and some very specific behavioral output. The organism is receiving many other inputs, has a long history of interacting with the environment, and has many organismic factors affecting the output. In addition, the organism is always exhibiting many many behaviors. It never does only one isolated thing.

Luckily, an approach is available which isolates just the input and output factors in which you are interested. The approach is based on the realization that a comparison with an untreated control removes all factors that are the same and leaves only those factors that are different.

Suppose that you want to measure the effect of the caffeine in coffee without measuring the effect of drinking the coffee itself. On the surface, this seems like

an insoluble problem. An apt metaphor for this experiment is trying to weigh the caffeine in a cup of coffee without weighing the coffee itself. This metaphor is illustrated in the following figure. Caffeine alone cannot be put on one side of the balance because it does not exist outside the coffee. To measure the weight of caffeine, you must have the caffeine in coffee. The weight of coffee itself is an unwanted but unavoidable aspect of weighing caffeine. It is a confound in that you only want to know the weight of the caffeine.

Amazingly enough, you can in fact weigh just the caffeine in coffee by canceling the weight of the coffee. If an exactly equivalent amount of coffee without the caffeine is placed on the other pan of a balance, it has the effect of removing the effect of the coffee on the weight of the caffeine in the other pan. Only the difference between the two pans (i.e., caffeine only) affects the weight indicator (i.e., dependent variable). Therefore, if you wish to measure the effect of caffeine without the coffee on behavior, then you give a person decaffeinated coffee on some days and caffeinated coffee on other days. In that way, only the difference in the treatments (caffeine) will be isolated and its effects can be measured as the difference between the behavior on coffee plus caffeine days and coffee without caffeine days.



An experiment can be seen as doing whatever is necessary to arrange exactly identical conditions on both sides of the balance except for the independent variable (e.g., the caffeine). Any difference in the dependent variable (e.g., the pointer) is caused by the independent variable. Any difference between the two experimental conditions in addition to the independent variable (e.g., cream in one of the cups) is a confound and is an error. In the pan balance example, only the caffeine can be allowed to cause the balance to shift from zero. In all other regards, the containers must be exactly equivalent.

The following simplified semialgebraic analogy may further illustrate the point. Suppose the nearly infinite number of possible stimuli (inputs) in a crowded cafeteria are represented as,

$$A + B + C + D + E \dots$$

(these are the contents of one pan in the above figure). And the equally nearly infinite variety of behavior (outputs) in that cafeteria is represented as,

$$\mathbf{V} + \mathbf{W} + \mathbf{X} + \mathbf{Y} + \mathbf{Z} \quad \dots$$

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

$$A + B + C + D + E \dots \rightarrow V + W + X + Y + Z \dots$$

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

 $A + B + C + D + E \dots + P \dots > V + W + X + Y + Z \dots$ 

Much to your satisfaction, the total behavioral picture in the room changes to include a smile, nod and a wave in return.

$$A + B + C + D + E \dots + P \dots > V + W + X + Y + Z \dots + S$$

A, B, C, D, E, and P can be seen as the causes for V, W, X, Y, Z, and S. However, we are actually interested in only a subset of all possible causes for the wave (S) (i.e., your smile (P). We don't really care about the smell of hamburgers or the clank of dishes. Additionally, we don't really care about all possible dependent variables (e.g., people moving around and talking). We really only care about the wave (i.e., S and your smile (P)).

You can apply a bit of reasoning and find that you can cancel all the stimulus factors that were the same before, during, and after your additional stimulus as being extremely unlikely candidates for causing the change in the mass of behavior in the cafeteria. The smell of hamburgers and the clanking of dishes occurred before, during, and after your mile. (Things that are the same on both sides of a pan balance cannot be the cause of a deviation in the pointer.) Your additional stimulus and the subsequent reply are the only events remaining after all the potential "causes" and "results" that were the same canceled. It is as if you could algebraically subtract the before from the after.

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

You could accept, therefore, that your wave caused the reply. Any difference in results must be because of differences in the causes.

Your reasoning was good as far as it went. Unfortunately you may find that you could have made an error in assuming too much. If all conditions were not the same (as they rarely are in a crowded cafeteria), all factors do not cancel out.

 (after)
  $A + B + C + D + E \dots + PQR$   $V + W + X + Y + Z \dots + S$  

 (before)
  $A + B + C + D + E \dots$   $V + W + X + Y + Z \dots$  

 /
 /
 /
 /
 + PQR ------>

 /
 /
 /
 /
 + S

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

In point of fact, your independent variable (P) can be thought to cause the change in the dependent variable (S) <u>only if all</u> factors cancel and are therefore proven irrelevant. Anything that changed and was not corrected for (i.e., Q + R) may possibly be the actual cause and lead to the possibility of alternative explanations for an obtained result.

As a result, variables that you are not explicitly testing must be kept constant. Remember that the idea of an experiment is to reduce or eliminate alternative explanations for what you are demonstrating. If you allow potentially relevant variables to fluctuate in an uncontrolled fashion you cannot be sure what caused the effect. Was it the result of the change which you deliberately manipulated or was the effect the result of the other simultaneous and therefore confounded changes? You are left with very little that you can say with confidence. A solution for the cafeteria example would be to stand with no one else behind you or add an additional test such as moving to a new spot and waving again, both of which would eliminate the likelihood of some other simultaneous event, which could be the cause.

Typically experiments contain two exactly identical conditions treated exactly the same except for the independent variable (your wave is the ONLY thing that is different). For example, two groups, one given a pill with a drug (experimental group) and the other with an identical pill without the drug (control group). This can be represented as

(experimental)  $A + B + C + D + pill \dots + drug \dots > V + W + X + Y + Z \dots + S$ (control)  $A + B + C + D + pill \dots + drug \dots > V + W + X + Y + Z \dots$  "drug" represents the independent variable; S represents the dependent variable. A + B + C + D + pill ---- represents contextual, constant variables. Any variable that you want to eliminate as a potential cause should be eliminated by making it the same in the control group. It will therefore be canceled out.

To accurately assess a functional relationship, you must make absolutely certain that the confounding influences have been removed or at least held constant so that they do not have a changing effect on different parts of the experiment. Your major adversary in the quest for truth is the uncontrolled variable. If uncontrolled variables could have been present you will not know for sure what, if any, effect the independent variables had had.

#### i. Group Design

In group designs, different groups of subjects serve in the treatment and control conditions. Clearly, the two groups must be as similar as possible and must be treated as much the same as possible, with the exception of the independent variable. In this way, everything but the independent variable cancels out as a potential cause for the difference in the dependent measures (any minute differences between the two groups or the treatment they received would be a confound).



#### ii. Single Subject Design

In single subject designs, the same individual serves as both the treatment "group" and the control "group." How the individual behaves under the treatment is compared to how that same individual behaved both before and after the treatment. Any difference in what the individual was exposed to (independent variable plus any other things that crept in) is thought to cause the difference in behavior.

Single subject designs are used because they provide the most powerful technology to detect treatment effects and provide the greatest generality to other situations. Single subject designs can detect very small differences (i.e., are powerful) because an individual typically behaves very similarly from day to day if the conditions are the same. For example, if the body snatchers replaced your close friend with a clone, you would probably detect something wrong because minute differences show up against the otherwise sameness of an individual. Group designs are not as powerful as single subject designs because any difference between two people may be the errors in the match between the real person and the clone or may be simply that those two people have different personalities. Single subject designs have very good generality because if every single animal exhibits the same functional relationship, then it is very likely that a target animal will also exhibit the same relationship.



The "before" and "after" conditions and their resulting behaviors of a single subject design are used to cancel out the effects of unwanted confounds as potential causes of the resulting behaviors during the treatment condition. Only the difference in the conditions are the likely causes for the difference in the behavior.

#### b. Cost Benefit Analysis

Further, to make matters even more difficult, the costs and benefits of decisions are not always equal. As a result, decisions must be based on a weighing of the pros and cons of each outcome and by comparing the net value to your "criterion" or the point you choose for when enough is enough. Science (as well as common sense and law) rejects capricious decisions. You cannot simply do whatever you feel like doing at the time.

A detailed, analytical example will help. Suppose you are camping out in very remote terrain and you hear a noise. What should you do? Go back to sleep? Run for a tree? Or, turn off the television and turn down the electric blanket? One of two actual events could have happened. A dangerous one or an insignificant one. You could behave in one of two ways: you could have reacted to the event, or you could have ignored it. The figure below illustrates the four possible occurrences.

		Reality	
		danger	insignificant
Your Choice	react	lifesaving escape	cowardly flight
	ignore	foodhardy death	peaceful sleep

If you ignored it when nothing was there (peaceful sleep) you got a good night's sleep and were safe. If you ignored it when there was danger you died (foolhardy death). If you reacted when there was nothing there (cowardly flight) you spent the night shivering in a tree for no reason. If you reacted when there was danger (lifesaving escape) you saved your life. Note that whatever you do (react or ignore) is the result of a decision.

You can examine two other everyday decisions with this same type of analysis. An accused person could, in fact, be guilty or innocent and you as a juror could vote to convict or exonerate.

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

A second example is given by dating. The other person could be willing or unwilling to go out with you on a date and you could ask or refrain from asking that person out for a date.

	willing	unwilling
ask for a date	get date	get turned down
don't ask	miss opportunity	save face

The abstract version of the decision matrix is presented in the following figure.

	noise + signal	noise
noise + signal	correct detection	false alarm
noise	miss	correct rejection

The two types of errors are inversely related; they work like a "seesaw." If you mindlessly minimize death, you maximize flight. If you mindlessly minimize flight, you maximize death.



If you must avoid being eaten at any cost, then that cost is an unavoidable increase in losing sleep for no reason (cowardly flights). If you must avoid sleepless nights at any cost, then that cost is an unavoidable increase in being eaten (foolhardy death).

As can be seen decisions are actually a trade-off. Given that you want to avoid being eaten (correct detection) how many sleepless nights are you willing to spend? If it is 100%, then spend all night every night up a tree with search lights on and a gun? If it is 0%, then don't worry about a thing – when your time comes you will be gone. If it is 1%, when you hear roaring and trees breaking, run for your life. That will save you once in awhile, but many times the bear will be quieter than that and you will die. The point is that you must choose a balance between gain and loss that is governed by how you evaluate or weight the two alternatives – which is the worst alternative and by how much? How many sleepless nights against how much safety. More correct detections cost more false alarms. More correct rejections cost more misses. Decisions actually concern the proportion of each type of error you are willing to tolerate, not whether or not something "really" happened. Your trade-off point is called your criterion. Given the criterion, the decision is simple and is based on simple math. You become a creature of rule rather than guess.

You could essentially say "be as safe as possible as often as possible up to about X nights per 100 up a tree for no reason." You could draw the limit at 5%, 10%, or 1%, or any other value. The following figure illustrates this process: for example, reduce foolhardy suicide as much as possible (push the left side of the seesaw down) until it starts costing (the resulting rise in the right side of the seesaw) more than five nights out of a hundred up a tree for no reason. Further decrease in the left side is blocked by the maximum tolerable cost on the right side. It is as if the right side of the seesaw hit a peg or ran out of slack in a chain bolted to the ground. The 5% false alarm rate is, of course, arbitrary and is applicable only when other issues are not involved but it is generally accepted as a reasonable plain vanilla criterion.



#### c. Assumption That Unlikely by Chance is True Effect

Given that you have removed confounds as a cause for your obtained results, you now must determine if the results were simply the result of chance or were the result of a true treatment effect. You are in a situation where you must decide whether or not a treatment was effective. The following figure illustrates the details of the task that faces us. Imagine four parties where the noise levels are sometimes very loud and sometimes very quiet. Also imagine the noise of someone knocking on the door, indicated by the arrows. The four figures show four intensities of door knocking. Add the task of having to decide if someone knocked at the door at the four parties. Suppose they just tapped the door? You would not distinguish it. Suppose they hit the door with a sledge hammer? Surely you would hear it. What about all the variations in between? If they continually knocked harder and harder, at what point would you just hear it? Any possible ratio of signal to noise could occur.



The continuous function below is the result of all possible signal-to-noise ratios four of which are illustrated in the above figure.

Unfortunately, the information upon which decisions are based is not a

simple step function like the dashed line in the following figure, rather it changes gradually and continuously like the solid line. Except in the most trivial of cases, decisions must be based on information which can take on any value. We cannot jump at every single noise nor can we wait for a sledge hammer. The infinite series of ratios, each one slightly larger than the one before, is also well illustrated by the increasing light levels with sunrise when the task is to decide when is it daylight.



Returning to the previous wind versus bear noise example, the actual distribution of events like wind noises in the woods is normally distributed. Events very different than the mean are unlikely to occur by chance. Very loud or very soft noises are not likely to happen in the woods by chance. The chance curve is depicted as the central Gaussian distribution in the following figure. It is filled with horizontal lines. For pedagogical purposes, we can depict the probability of two classes of events which are dangerous with areas filled with vertical hatch marks one above and one below the distribution of wind noises. Bears make a lot of noise, so the distribution of the noises they make is louder than the wind. Big cats make almost no noise and, in fact, cause the crickets and things to be still so the distribution of noises when they are around is actually lower than background noises. Note that the two distributions of dangerous animal noises actually overlap the distribution of wind noises. Some bear (loud) noises are actually relatively quiet (to the left of some wind noises). Similarly, the right tail of the distribution of tiger noises is actually relatively loud (to the right of some wind noises). The two dangerous distributions are arbitrarily set to be Gaussian and to have their lowest at approximately the mean of the distribution of noises caused by chance, but their minimum, maximum, and shape actually depend on several factors which are virtually always unknown. For pedagogical simplicity, sounds (more precisely the production of quiet) from the tiger distribution will be ignored in future discussions (they are, in fact, identical in all regards to bear noises with the exception of being to the left rather than to the right of the wind distribution).

A very loud sound (Point F on axis) is very unlikely to be the result of the wind or simply background noise. In a simplistic world where only two types of things can happen, wind or bears; then less probability that something is wind implies that it is more likely to be a bear. We cannot always make that inference however. It can be seen that as we shift our criterion of when to run for our lives from C to D to E, and F we will be making fewer and fewer false alarms. We will be a coward less often. (The area under the chance curve beyond the criterion.) The horizontal cross-hatched area beyond our criterion will be smaller and smaller <u>but</u>, for this hypothetical distribution of bear sounds we will make more and more misses (the area under the effect curve within the criterion, i.e., the vertical cross-hatched area to the inside of our criterion will be larger and larger).



If we set our criterion for running for our lives to Points D and B we can illustrate the four possible outcomes of the decision matrix keeping in mind that the horizontal lines depict the chance curve and the vertical hatch lines illustrates only two of an infinite number of possible effect curves.



The logic underlying your decision is: 1) if the magnitude of the signal is really quite large compared to what happens by chance, then you are willing to accept that it was not chance (even though it could be chance), 2) if it was not chance that caused the signal, then if you do the treatment again, you will probably get the effect again (it is a reliable effect), and finally, 3) if the treatment reliably causes that effect, then the treatment "really works."

In sum, given that a result is not caused by a confound, a treatment effect is accepted as real if it is unusually large. If an effect is larger than our criterion, we declare that we are willing to accept that the treatment worked. Our criterion is a rationally determined point based on what happens by chance, and our relative valuation of false alarms and misses. When making research decisions, we do not guess nor make them with divine knowledge, rather they are statistical decisions. Just as in dice throwing, when we bet on a 7 rather than a 2, we don't know which toss will win in each situation, but we do know what to bet on in order to be right more often than not.

## 2. Two Basic Steps in Research Design a. First: Eliminate Confounds

First compare two conditions which are exactly equal with the exception of the independent variable. The underlying logic is that differences in results are caused by differences in procedures. Any difference in the result of those different treatments must be due to chance or true effect. The control condition or control group eliminates confounds as potential causes.

## b. Second: Compare to Criterion for When Enough is Enough

Determine what happens by chance. Set your criterion to specify how many false alarms you are willing to make or that you can afford. If your obtained results exceed your criterion, then declare a true effect.

## 3. Conceptual Follow-Up: Chance, Confound, and True Effect

As previously discussed, the outcome of any experiment can be the result of three causes: confound, chance, and true effect. Each investigator is obligated to consider each and make a case for which of the three was the most likely cause of the outcome. After rejecting confound as a cause, it is always possible that the result was only chance. Researchers deal with this by establishing a criterion, past which they are willing to <u>claim</u> a true effect. Ultimately, it doesn't matter if the effect was <u>really</u> a true effect because we will never have divine knowledge. Most often, researchers are unwilling to claim a true effect if the result was likely by chance. If you try to mentally cause a head to come up when you honestly flip an honest coin once, and it comes up heads it is not a wise idea to declare that you have telekinesis. If you are in a different situation.

Experiments which produce results very unlikely by chance can either indicate the action of a confound or the action of a true effect. We normally know that the result is not due to a confound because we generated a control "treatment" which was exactly the same as the treatment except for the independent variable. The confound was removed by cancellation. We are, therefore, left with only a true treatment effect as the probable cause.

#### C. Research Tactics

The following are some attitudes or tactics which are likely to bring you success in your research endeavor.

## 1. Be Committed

Nature does not give up its secrets easily. Choose a topic for which you will be willing to spend a great deal of time thinking about and working on. Have confidence in your own judgment (but, note #5 below). Be enthusiastic. Work in a social situation which keeps you working and thinking. Create the social situation which will provide the reinforcers you need if necessary. Simply put: Knowledge and insight, like muscles, come from hours of work.

## 2. Be Well Read

Building on the discoveries of others is very much more productive than reinventing the wheel. Reading time will pay off vastly more than "doing" time because it takes only a few hours to read a paper while it takes many hours to redo the experiment necessary to discover the empirical relationship, and many many hours to realize what those data mean. Use reading time to get wisdom and to spark ideas. Use "doing" time to clearly prove that you were right or wrong.

## 3. Balance Novel and Mainstream

Strike a balance between following the existing paradigm with tried and true procedures and tried and true conceptualizations, and breaking new ground with new conceptual approaches. Old ground is safe but boring. New ground is exciting but risky. The problem is similar to building a productive stock portfolio.

## 4. Focus on Productive Relationships a. Reliable Robust Relationship

Independent variables which produce large effects or consistent effects are easier to measure and are easier to separate from random noise and confounds.

## b. Apt and Optimal Elements

Choose an optimal subject, apparatus, and procedure to research potential relationships. It is easier to use pigeons than whales as subjects. It is easier to detect a movement which activates a switch, than to detect the dipping of a wing in free space or the behavior of thinking some thought. It is easier to control the presentation of food to a hungry organism than to control "life's little pleasures."

#### c. Large Potential for Gain

Some pieces of knowledge are simply more useful than others. Articulating a functional relationship which dramatically reduces the complexity of the existing

paradigm, or which is a counter example in a previously coherent paradigm, provides a greater step forward than some finding which does not bear on anything apparent. While it is true that that finding may turn out to be critical, it is the additional subsequently gathered information that makes it so.

## 5. Maximize Your Chances to Discover a. Simplify to Essential Case

Discovery is much like mining and refining. First we must uncover a relationship and then we must separate the inessential and confusing from the actual effect. We want to eliminate the uncontrolled variability which obscures the important effect. In sum, the insightful use of simplicity is a very powerful research tool. It often is labeled research elegance.

## b. Sort in Terms of Similarities and Differences

If you sort phenomena into positive and negative instances, then you can define the boundary which separates them. That separation rule is a major advancement in our knowledge. Just the same as finding the outline of the steam shovel at the bottom of the lake or a follow-the-dots picture would make it obvious what it was.

## c. Search for Regularities

Regularities provide you with a method of simplifying the booming confusion of nature. A single simple rule can extract or make comprehendible much of the obtained variance. For example, the fluctuating activity levels of an organism can be better understood by noting how it shifts with the light cycle.

## d. Optimize Visualization

Some ways of characterizing complex relationships are better than others. Your task can be made very much easier with the right visualization, often a clear graphical depiction of a relationship simplifies its understanding. Analytical geometry was almost as great a step forward in our thinking as was language.

In general, it allows you to see many complex relationships as simple spatial relationships.

## e. Be Open-minded

Be careful not to fixate on a judgment error and try to prove it at all costs. Sometimes what we strongly believe or hold dear turns out to be wrong.

### f. Recognize Errors as Breakthroughs

If you make a wrong prediction either you discovered something about yourself or you discovered something about nature. In either cases you have gained because you or your model will be better the next time.

#### g. Drop Everything if Necessary

While seeing a problem through to completion is almost always the only acceptable research methodology, occasionally, a finding of such great significance occurs that we should drop everything and pursue the new problem.

#### 6. Be Alert, Ingenious and Relentless

Be curious, ask yourself why things are the way they are. Try to understand your world. Knowledge will not be dumped squeaky clean into your lap. It will be like trying to find the dolphin in the preface; you will have to actively make it make sense. If the knowledge has already been discovered, someone can tell you where to look and generally what you should see. But you are not trying to come to see what people already know. You are trying to discover something that no one has yet found. This is more difficult. If you are to be the first, then no one can show you where to look and what you should see. You will have to discover it for yourself. No one can guarantee that you are doing the right thing.

Some researchers have said that the task is like the mental equivalent of passing a truck in the rain. In order to advance, you must enter and successfully pass through a period of intense confusion. Success is not guaranteed. In fact, nothing can guarantee that a solution is even possible. The confusion is intimidating and makes you want to stop or turn back. But, if you make good decision and stay the course, you pass through to clarity and you are much further ahead. The intimidating power of confusion is easily illustrated by the difficulty of maintaining attention. Dividing 3 digits into 6 digits in your head is difficult, and requires intense and continuous attention. The effort makes you want to stop. But, if you stay the course long enough to find the answer, that answer is an easy thing to remember and use. The difficult, scary, unclear, and bewildering challenge of discovering a conceptual solution to a new problem is sometimes referred to as "working your way through the fog of confusion."

#### 7. Be Diligent, Meticulous, and Scrupulously Honest

Keep in mind that, if other researchers are to use your data and interpretations when they build their theories (i.e., your reinforcer), then they must trust you implicitly. If your data was in error or you were not correct in your inference, then their theory will fail (i.e., their nightmare).