CHAPTER ONE

SETTING THE PROBLEMS

There are fashions in psychological theorizing that appear periodically over virtually the entire history of the field. Not unlike fashions in wearing apparel, styles of thinking tend to recycle, typically reappearing in somewhat modified form. This indicates that early explanations may have had some value and are, therefore, to be preserved in some form in contemporary explanation. If it is possible to determine why a system eventually fails, and why it returns at a later date in a different form, it will be possible to understand more clearly the possibilities for explanatory success regarding a particular class of empirical phenomena. This, in turn, requires that the general assumptions and conceptual contexts which psychologists have used to solve their problems be enumerated. Because many current psychological explanations may be subsumed under one of the more general behavioral or cognitive rubrics, the difference between these systems is at the center of the discussion. There is a long history to the separation of behavior from cognition as the principal positions from which human activity is explained. One of the most crucial results of this history is the opposition of these two approaches in explaining the nature of any social phenomenon. Perhaps the principal point of contention between the behavioral and cognitive positions is over the causative sources of human activity. A brief historical review of this issue follows.

The Locus of Control

From what source human behavior is produced has been a periodically occurring issue in the history of psychological explanation. The characterization of some of the more profound differences among encompassing theories of human behavior usually results in theorists either dismissing or ignoring opposing theories out-of-hand. We shall see examples of this in ensuing chapters.

To my knowledge, no contemporary psychologist invokes God as the determiner of human existence or of human activity. Whatever a theorist's beliefs may be about the idea of a personal god, these beliefs have not typically entered into the development of psychological theory addressed to any aspect of human phenomena. That being said, the locus of control of human behavior can only be set in one or both of two places: within the organism or within the environment of the organism. Virtually without exception, modern psychologists are interactionists of one sort or the other in that they believe that it is not possible to eliminate either internal or external organismic conditions in deciding about the determiners of human activity. There are no longer strict nativists nor strict environmentalists when it comes to building psychological theory. However, it is clear that some psychologists have chosen problem areas in which internal organismic conditions are emphasized as the determiners of human action and other psychologists have chosen problems in which environmental conditions are considered to be the major determiners of human activity. The questions that have currently arisen are concerned with the relative contributions to understanding human activity made by genetic conditions as compared with those contributed by the environment.

It is astounding how resilient the mind–body dichotomy has been in psychology although it has been expressed in increasingly more sophisticated terms over the course of the last two centuries. The modern issue is one of determining the locus of control or, more precisely, causal efficacy with regard to human activity. As we shall see later, the recent appearance of deconstructionist, contextual considerations even challenges the very idea of causal efficacy as it has functioned in predictive psychology. In addition, Rychlak (1977, 1992) proposes a teleological empiricism which emphasizes the difference between the pursuit of efficient and material causes by the behavior analysts and the pursuit of formal–final causes by more teleologically oriented psychologists.

Although the dichotomy is undoubtedly ancient, the idea that the human body functions differently from the human mind (without worrying now exactly what are meant by these terms) was codified in modern Western thought by Descartes in the seventeenth century. Mind operating at its best was clear and distinct thought and was the source of the knowledge of human existence itself (cogito ergo sum). The body operated by mechanical principles and interacted with mind at a particular place in the brain. Those following Descartes had a choice in their study of human existence to examine either the way the body worked or the way the mind worked. They were to become very different enterprises. By the eighteenth century, Locke, Hume and others began the process of placing the body's function at the center of their studies. By so doing they drew the idea of the way mind functioned closer to their idea of the way body functioned. The "idea," the central term of mind, was seen as developing from impressions, what we today would call sensations. An impression occurred when one sensed an object, that is, saw it, heard it, smelled it, tasted it, felt it. When a mental picture of this object was experienced in its physical absence, this was said to be a simple idea. Complex ideas were made up of simple ideas which were combined by the process of association. The delineation of the principles of association, of course, was to occupy the so-called British associationists for many years. By interpreting the simple idea, to be produced by a physical object, Locke and Hume achieved a kind of fusion between the concept of body and that of mind, or at least indicated how they could both be part of a continuous process (see Lana, 1991, for a more complete discussion of this issue). By the nineteenth century the interests of the natural scientists and the philosophers had sufficiently diverged so that it can not unreasonably be said that scientists were concerned with explaining body and philosophers with explaining mind. With the development of a formal psychology in the latter part of the century, psychologists participated in the mind–body debate from a somewhat different prospective.

The work of Wilhelm Wundt and others resulted in what has been called "content" psychology. It was to be one of the two dominate epistemologies employed in psychology in the 1870's. Most of the research done under this rubric was conducted on the nature of perception. Psychophysical techniques such as the method of just noticeable differences, the method of constant stimuli, and the method of average error, along with introspection (*Selbstbeobachtung*) constituted the experimental approach of the content psychologists. Perception was the active process that allowed one to know the content of consciousness (mind) and, indeed, was consciousness itself. This belief, coupled with a strong interest in experimental method, led the content psychologists to examine the processes of sensation in many of its manifestations. The general idea was to reduce the various states of consciousness to their perceptual and sensory components. "Act" psychology was eventually differentiated from the content approach by Franz Brentano who is given credit as its theoretical originator.

For content psychologists a given perception was composed of its individual sensations. A perceived red sweater is the sum of the sensations of the color red, the sensations of appropriate length, width, texture, etc. A difficulty arose when certain perceptions seemed to be more than a simple summation of sensations. For example, the visual sensation of the right eye combined with that of the left yields a perception of depth which could not be accounted for by the summation of the individual sensations of the right and left eyes alone. A tune is similarly perceived as more than the summation of hearing individual notes. The active quality of perception seemed to be more than the mere sensations of which it was composed. The act psychologists concluded that the process of perceiving was of greater importance than the content of which it was composed. Act psychology provided the context in which gestalt psychology eventually developed. Even though the act and content psychologists represented two distinct positions, they both addressed the issue of how mind or consciousness worked. These positions were more sophisticated than those of previous centuries because both the physiological characteristics of the sensory apparatus and objects in space were given parts in the explanation. It remained for the twentieth century to provide the context for a clear interest in behavior to emerge.

The work of John Watson (1913) and other early behaviorists is well known and a review of their achievements in not necessary. It is clear that Watson's focus on behavior set him in contradistinction to both content psychology and act psychology. Consequently, by 1913, the old mind–body distinction had evolved into the more complex issue of whether to study consciousness in either its form or content, or to study behavior which consisted, at least for Watson, of observable body movements. In short, Watson allowed the sense experience of the observer as the only acceptable data for the scientific study of human or other animal activity.

With the work of B.F. Skinner, the basic assumptions and procedures of the behavioral position reached their current level of complexity and sophistication. Skinner's contention that behavior is a result of its consequences and that thinking, speaking, and indeed, most everything that animals do, *is* behavior, sets his position as continuous and consistent with that of Watson. Paralleling this development, the contemporary conceptual derivatives of the content and act schools, with their focus on consciousness, became the epistemological basis of cognitive psychology.

The so-called cognitive revolution (for example, Baars, 1986) was presumably a reaction against the dominant theoretical position represented by various forms of behaviorism in the 1950's and 1960's in North America. This reaction was not unlike Watson's in 1913 that established behaviorism as an alternative approach to the act and content schools. When Skinnerian behavior analysis emerged as the survivor among the various behaviorisms of the 1930's and 1940's, there were psychologists who remained in opposition to the contention that human activity was essentially controlled by its consequences in the environment. The organism seemed empty even though behavior analysis allowed for the possibility of genetically determined characteristics with the concept of the behavioral repertoire. The behavioral repertoire not only accounted for the genetically determined responses of which the organism was capable, but also contained those acquired responses which were available to the organism under appropriate environmental conditions. In short, pigs don't fly and birds do because of their genetic endowments and people who have learned how to swim do not do so unless they are in water. Despite the fact that the concept of the behavioral repertoire covered the built-in possibilities for behavior, the behavior analysts themselves never made much of the concept. The interest of most of them was to search for the various environmental conditions which were linked to particular responses. Genetic endowment was minimized and environment maximized in most behavior analytic experiments and in interpretations of human behavior. Consequently the emphasis of behavior analysis (rather than its stated principles) probably diverted the attention of many psychologists toward looking for alternative theoretical explanations of the more complex forms of human behavior. Since most theorists agree that the acquisition and use of language is likely the most complex form of human behavior, cognitivist psychologists interested in language and thought departed from the theoretical context of behavior analysis. This departure virtually required the separation of language from thought since natural languages are clearly acquired, but patterns of thought may be part of the genetic endowment of the human organism. This separation will be discussed below in the chapter on cognition.

Skinner and the behavior analysts, of course, did not avoid attempting to explain the acquisition and use of language. Skinner's *Verbal Behavior*, published in 1957, probably deserves some credit in establishing the beginning of the current era of interest in the cognitive. Noam Chomsky's lengthy review of this work and Skinner's lack of an immediate response to it, established an alternative explanation to the behavior analytic view by insisting upon the necessity of a description of genetically determined conditions in order to understand the nature of thought and language.

Methods

The behavioral and cognitive approaches utilize certain methodological techniques to gather information and these need to be enumerated since they deepen our understanding of the theoretical positions they serve. Following is a description of the axiomatic, the quasi-axiomatic, the correlational, and the hermeneutic approaches to gathering and ordering data.

1. The Axiomatic Approach. Structuring information in an axiomatic form was championed as the most desirable approach to understanding human behavior in the 1920's and continued for some years afterward. The success of the axiomatic approach in physics, chemistry, and biology wet the appetites of those psychologists who believed that a similar approach was possible in their own field.

2. The Quasi-Axiomatic Approach. The failure of utilizing the axiomatic as a method of gathering psychological information was followed with what I wish to call quasi-axiomatic thinking. This consisted of hypothesis testing in a formal manner, but where a set of postulates, axioms, and corollaries were not necessarily part of the process.

3. The Correlational Approach. Recently, the hypothesis testing, quasi-axiomatic approach was challenged by psychologists who favor a more correlational approach to the examination of empirical data. The emphasis is on discovering the degree of relationship existing between any independent variable and the dependent variable.

4. The Hermeneutic Approach. The lack of success in the approaches borrowed from the natural sciences by areas of psychology which are particularly concerned with whole person interactions leads to a consideration of the fundamental differences in the nature of the data associated with social situations compared with physical or biological ones. The tentative conclusion drawn is that social interaction depends heavily upon, and is partly synonymous with, language. Language is both the medium through which all explanation is expressed and is the explanation itself. Since important human interaction occurs through language or *is* language (the issue remains open at this point), its acquisition and use must be examined. If we understand how language works, we understand both how explanation works and how people work socially. Much of the analysis of the nature of language and of social activity can only be hermeneutic in both historical and current contexts. This issue is discussed in some detail in Chapters 7 and 8.

Axiomatic Thinking in the Natural Sciences

The three principal natural sciences, physics, chemistry, and biology, eventually embraced the axiomatic method in order to meaningfully arrange their empirical discoveries. Axiomatic method refers to the process whereby consistent empirical observations are arranged in a manner such that they can be stated in a mathematical or quasi-mathematical form so that all inferences from one statement to the other are logically consistent. Although logicians sometimes use different labels for the same process, the axioms of a formal scientific system contain its content. The axioms thus contain all of the theorems in the system since these are derivable from the axioms. Postulates relevant to the axioms function the way premises do in deductions made within the system (Kyburg, 1968). They are its formal properties. Postulates allow formal derivations to be made from axioms which suggests relationships concerning the phenomena under study which have not as yet been observed. Should these statements indicating as yet unobserved arrangements prove to be predictive, the axioms from which they were derived gain a certain increment of validity.

The labeling of what constitutes a postulate and what is an axiom is not always clear in any particular presentation of a scientific deductive system since axioms are sometimes said to play the role of meaning postulates (Kyburg, 1968) In any case, the following logical methods of procedure are typical of postulates or rules of inference utilized in most formal and informal axiomatic systems:

Definition of symbols: "~" is "not"; "v" is "or"; "&" is "and"; and ⊃ represents "if . . . then . . ." (A includes B, the conditional).

1. Modus ponens: From premises A and (A ⊃ B) B may be inferred.

2. Modus tollens: From premises ~ B and (A ⊃ B), ~ A may be inferred.

3. Hypothetical syllogism: From premises (A ⊃ B) and (B ⊃ C), (A ⊃ C) may be inferred.

4. Disjunctive syllogism: From premises (A v B) and ~ A, B may be inferred.

5. Simplification: From premise (A & B), A may be inferred.

6. Conjunction: From premises A and B, (A & B) may be inferred.

7. Addition: From premise A, (A v B) may be inferred.

8. Replacement: If A and B are logically equivalent, and C is like D, except for containing one or more occurrences of A where D contains occurrences of B, C may be inferred from D. There are several truth-functional equivalents which may be considered part of the rule of replacement and which define "logical equivalence." They are DeMorgan's laws, distributive laws, associative laws, commutative laws, double negation, transposition, exportation, and conditional law. It is not necessary to discuss these laws for purposes of the current exposition. They are listed only for completion of the replacement inference rule.

Explanation in Physics

How bodies move in space was the initial problem that occupied most physicists in the fifteenth century and for many years afterward. The wedding of the movement of objects with certain mathematics insured a rapid progress in understanding. The vector, a generalization of the number concept, designates the direction of movement of an object which can be assigned a number. That is, physical quantities often behave like mathematical vectors in combining factors from different sources to produce the final direction and speed of an object. A bi-dimensional Cartesian vector is a similar concept familiar to all psychologists. The presentation of experimentally generated data by way of Cartesian coordinates allows for a rapid assessment of the change in the dependent variable as a function of the proportional change in an independent variable.

In kinematics, the science of movement, space and time are basic or primitive concepts and velocity and acceleration are derived from them. That is, movement through space over time or, more formally, the rate of change of the position of an object with respect to time, is velocity. Acceleration is the rate of change of velocity with respect to time. Both are vector quantities. From this we get $x = x_o + vt$ where $t = 0$ and $x_o = 0$ (object at rest). Then $x = v$, the velocity. If graphed the result is a straight line (linear) function. This conclusion was confirmed experimentally by Galileo. In Galileo's experiments of spheres rolling down inclined planes, the force of gravity is the same in all cases (straight down), but the other component of the vector (the slope of the board) can be made to vary; hence the acceleration of the ball is different in each case and proportional to the force exerted along the board (given by the board's angle).

These experiments eventually inspired Newton to write the first law of mechanics (inertia): every body continues in a state of rest or of uniform motion in a straight line unless it is compelled to change by forces exerted on it. Or a (acceleration) = 0 when F (force) = 0. The remaining laws of mechanics were similarly developed by combining vector mathematics with experiment. The result was that many true statements about the movement of objects in space could be formally derived from a few mathematically stateable principles. The method was so successful that it was taken as the ideal scientific way of proceeding well into the twentieth century. The ability to create meaningful experiments using appropriate controls and expressing the relationships discovered in the experiments in generalities was applicable to unobserved phenomena through logical derivation. Neptune was discovered in 1846 by a logical derivation made from Newtonian mechanics. That is, the empirical affirmation of the planet's existence through telescopic observation occurred after the derivation had been made.

Explanation in Chemistry

Through experimentation from the seventeenth century on, it became increasingly evident that all of the organic and inorganic material of the universe was composed of a few basic substances labeled elements. These elements could be characterized by their atomic weights. In 1808, Dalton began to codify these weights and in 1813 Berzelius created the letter code which remains with us today. By 1860 about 60 elements composed of distinct atoms had been discovered. Today we count more than 90 earth elements although other highly unstable elements have been constructed in the laboratory and also appear in other celestial bodies.

Once these basic structures were discovered, the question arose as to how they combine to form the various compounds found on earth. The Periodic Table of the Elements indicates similarity in potential for combination of the elements in ratios relative to another element, for example hydrogen (Williams and Fraústo-da Silva, 1996). After the two lightest elements, hydrogen (H) and helium (He), there is a period (row) of eight elements from lithium (Li) to neon (Ne). Across this period the combining numbers with hydrogen are, in order, 1,2,3,4,3,2,1,0. These are shown in Figure 1. These numbers indicate the number of H elements binding per atom of X element. Helium, a noble (inert) element, does not combine with hydrogen. The Periodic Table, thus, indicates the combinatorial chemistry of atoms. In addition, the physical properties of the elements, such as apparent atomic volume, follow the same periodic trends as the atomic number.

Similarly to the basic laws of mechanics, the Periodic Table of the Elements serves as a basic set of principles from which can be logically derived the existence of unobserved entities such as elements with atomic

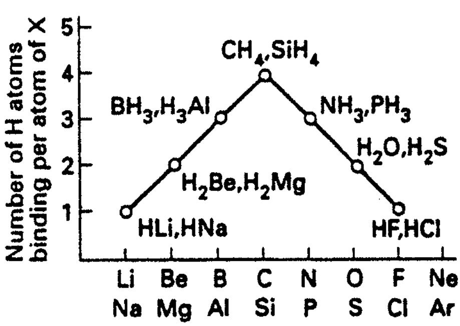

Figure 1: Number of hydrogen atoms binding per atom of element X in the two eight element periods comprising atomic numbers 3–10 and 11–18 from Periodic Table of the Elements. From Figure 1.8, p. 10, of Williams, R.J.P., and Fraústo-da Silva, J.J.R. (1996), *The Natural Selection of the Chemical Elements*. Reprinted with permission of the Oxford University Press, Oxford, United Kingdom.

numbers not discovered on earth, but capable of being manufactured and of existing in other celestial bodies. That is, the same method of combining observation with mathematical expression and logical deduction are involved in the advance of chemistry as it has been in physics.

Explanation in Biology

Biology today is so heavily dependent upon theory in chemistry that its axiomatic basis can be, in part, taken to be the same as that represented by the Periodic Table of the Elements, and it is so presented in contemporary textbooks (e.g., Baker and Allen, 1982). The strongest link between the theoretical structure of biology and that of chemistry is expressed in the analysis of the structure and function of the living cell. Axiomatic theorizing in biology which is independent of that of chemistry is, however, evident in a number of areas. The concept of homeostasis, developed by Walter Cannon in the early twentieth century, holds that physiological control mechanisms are apparently operating in the interaction of various body organs such as the stomach, mouth, pharynx, esophagus, intestines etc. which tend to keep various bodily conditions in a desirable equilibrium. The equilibrium can be static or dynamic. That is, these organs function either to prevent changes from occurring (static) or to regulate changes so that the result is a more-or-less constant organismic state (dynamic). For example, a constant level of carbon dioxide, salt, and glucose is maintained in the liquids of the body by the interaction of those organs involved in food intake and dissipation. This internal environment is maintained in a more severely changing external environment. Another example is the maintenance of a constant body temperature by warm-blooded animals. Shivering increases body heat when it is externally cold and perspiring decreases it when it is externally hot.

Since the principle of homeostasis can be applied to many processes in the body involving different sets of interacting organs, deductions can be made from it which can be examined experimentally. In short the same capability of being able to use a single set of principles in an axiomatic manner to explain apparently diverse activities, such as the maintenance of certain substances in the blood and the maintenance of a constant body temperature, exists in biology as it does in physics and chemistry. The relatively recent discovery of the helical structure of the DNA molecule also increases the axiomatic power of the field of biology as well.

Explanation in Psychology

Perhaps the clearest and most definite statement about the need for psychologists to embrace the axiomatic method, so successfully applied in physics, came from Clark L. Hull and his colleagues (Hull, Hovland, Ross, Hall, Perkins, and Fitch, 1940). The *Mathematico–Deductive Theory of Rote Learning* was an early attempt to arrange certain relatively simple psychological data in a manner that would allow both accurate prediction and the expansion of knowledge through deductive reasoning. In this effort, Hull distinguished between unobserved entities needed for theoretical development as being either (1) temporarily unavailable because technology trailed theoretical development, or (2) as being inherently unobservable. Hull mentions that Harvey postulated the existence of capillary vessels before they were actually observed microscopically. His theory of the circulation of the blood required the existence of something like capillary vessels. Harvey's "anastomosis (union) of veins and arteries" is an example of a temporary class of unobservables. Hull indicated that some theoretical concepts, even with improved technology, may turn out not to be observable, but may still be retained since no better concept presents itself to account for the data encompassed by the theory. In this case the first type of unobservable becomes an unobservable of the second type. There are difficulties with Hull's distinction since the second type of unobservable seems to be, by definition, a term referring to a constant source of potential error. However, this distinction between types of unobservables indicates that Hull was keenly supportive of the idea that psychological theory needed to embrace the deductive process in a formal way so that a theory could lead to observations that would not have been discovered without application of the theory.

By 1943, Hull extended the idea of an axiomatic approach to organizing psychological data to basic learning theory. Data gathered over years of research were used to form his *Principles of Behavior*. We are able to appreciate the scope of the task Hull set for himself from the very first lines in the preface to the book:

> As suggested by the title, this book attempts to present in an objective, systematic manner the primary, or fundamental, molar principles of behavior. It has been written on the assumption that all behavior, individual and social, moral and immoral, normal and psychopathic, is generated from the same primary laws; that the differences in the objective behavioral manifestations are due to the differing conditions under which habits are set up and function. Consequently, the present work may be regarded as a general introduction to the theory of all the behavioral (social) sciences. (p. v)

To most current psychologists this opening statement is staggering in its ambition. Hull's hope was to subsume what has become the data of learning, psychopathology, personality, and social psychology under certain basic principles that he believed to be obtainable by careful experiment and the hypothetico–deductive (axiomatic) method. He sought not less than a psychological equivalent to Newton's laws of motion in physics or chemistry's Periodic Table of the Elements. His goal may have been the most ambitious in the history of formal psychological theorizing.

In the empirical areas discussed here, physics, chemistry, biology, and psychology, the axiomatic approach has been prevalent at least in the early history of the various fields. In the natural sciences it has, of course, remained important to the enterprise. In psychology the issue is more complicated. A hypothetico–deductive or axiomatic approach is characterized by (a) a set of definitions, (b) one or more postulates or axioms which are principles about the empirical phenomena under study, and (c) statements referring to specific observed events which are logically derived from the postulates. It is to be noted that Hull labeled his primary meaning statements "postulates" rather than "axioms" as is more usual. However, any differences are merely one of labeling, not of procedure (as will be made clear below). The strength of this postulate system is increased to the extent that the observed events which the system predicts actually occur. If the system is successful it will be able to make logically derived statements which refer to potential occurrences which are then confirmed by observation. Hull (1943) indicated that Newton began with seven definitions involving matter, motion etc., a set of postulates containing the three laws of motion, and 73 formally proved theorems with a large numbers of corollaries. Hull set himself the same task in studying what he conceived to be the basic laws of behavior. When Hull spoke of his effort being to elaborate the basic molar laws of behavior underlying the "social" (Hull's quotation marks) sciences, he made explicit that he expected that it would eventually be possible to ascertain the relationship between physiology and external behavior. He believed that someday neurological science through the development of laws would be sufficient to constitute the basic principles of a science of behavior. His effort would be, by his own declaration, provisional and he would rely on what he thought to be ". . . the coarse, macroscopic or molar action of the nervous system whereby movements are evoked by stimuli . . ." (Hull, 1943, p. 20). His hope was that his work would aid in the development of such a physiology of behavior. He was keenly aware of the fact that various psychologists working on behavioral issues might disagree with one another for no greater reason than that they were considering different, more or less coarse, levels of behavior. He chose to keep the causal elements small (circumscribed) so as to be as close as possible to microscopic, (physiological) causative factors.

Hull acknowledged that some of the concepts he used in his molar theory of behavior referred to invisible entities. His concept of habit was just such an example. Habit presumably existed as an "invisible condition of the nervous system" (p. 21). The "habits" of swimming or automobile driving existed just as much when an organism was sleeping as when it was swimming or driving. The only place Hull could conceive of the behavior of swimming and driving potentially existing was in some more or less permanently changed condition of the nervous system after the individual had learned to swim and drive. Since it was not then possible to observe that condition responsible for the behavior in question, one had to describe the molar event which was available for examination. Hull concluded that the number of learning trials experienced by the organism was directly correlated with the unknown physiological changes in the nervous system. Number of learning trials was taken as the operational definition of habit strength with the implication that the condition of the nervous system changed incrementally with the increasing number of learning trials.

Hull begins by defining the terms which were used to compose the major postulates of his system — stimulus, response, stimulus object, continuum, receptor organ, afferent and efferent neural impulses etc. He does not acknowledge that the rules of inference and of standard logic and mathematics which he uses are axiomatic and instead states that there are no assumed axioms, meaning rules of procedure, in science. After citing appropriate research, he composes the first postulate of his system. Postulate 1 reads:

> When a stimulus energy (S) impinges on a suitable receptor organ, an afferent neural impulse (s) is generated and is propagated along connected fibrous branches of nerve cells in the general direction of the effector organs, via the brain. During the continued action of the stimulus energy (S), this afferent impulse (s), after a short latency, rises quickly to a maximum of intensity, following which it gradually falls to a relatively low value as a simple decay function of the maximum. After the termination of the action of the stimulus energy (S) on the receptor, the afferent impulse (s) continues its activity in the central nervous tissue for some seconds, gradually diminishing to zero as a simple decay function of its value at the time the stimulus energy (S) ceases to act. (Hull, 1943, p. 47)

By a similar assessment of the results of various experiments, Hull eventually developed sixteen postulates or major principles from which he derived many theorems and corollaries. Number 4 was the most well-known of the postulates:

> When ever an effector activity ($r \rightarrow R$) and a receptor activity ($S \rightarrow s$) occur in close temporal contiguity ($_sC_r$), and this $_sC_r$ is closely associated with the diminution of a need (G) or with a stimulus which has been closely and consistently associated with the diminution of a need (G), there will result an increment to a tendency ($_SH_R$) for that afferent impulse on later occasions to evoke that reaction. The increments from successive reinforcements summate in a manner which yields a combined habit strength ($_SH_R$) which is a simple positive growth function of the number of reinforcements (N). The upper limit (m) of this curve of learning is the product of (1) a positive growth function of the magnitude of need reduction which is involved in primary, or which is associated with secondary, reinforcement; (2) a negative function of the delay (t) in reinforcement; and (3) (a) a negative growth function of the degree of asynchronism

(t') of S and R when both are of brief duration, or (b), in case the action of S is prolonged so as to overlap the beginning of R, a negative growth function of the duration (t'') of the continuous action of S on the receptor when R begins. (Hull, 1943, p. 178)

The best known of Hull's predictive formulas was extracted from Postulate 4 which became known as the "drive-reduction postulate." That formula reads:

$$_{S}E_{R} = f(_{S}H_{R}) \times f(D)$$

Or, reaction evocation potential equals habit strength times drive under the assumption that all other relevant variables are constant.

Hull described how Postulate 4 and this predictive formula derived from it were developed based upon data gathered on albino rats by Perin (1942) and others. Habit strength ($_{S}H_{R}$) is a direct function of the number of learning trials, and drive (D) is variously defined, but for example, can be the number of hours of food deprivation. It can be shown that $_{S}E_{R}$ (in this case the reciprocal of the speed of running a straight alley) is the result of the multiplication of the values of habit strength and drive. The multiplicative relationship between $_{S}H_{R}$ and D is indicated by the negatively accelerated slope of the curve over various values of the two conditions as shown in Figure 2.

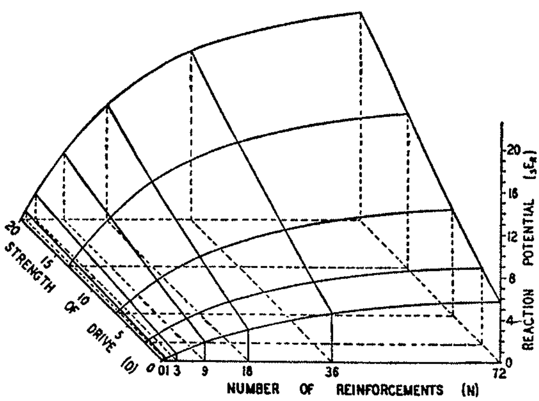

Figure 2: The hyperbolic function showing the increase in performance as a result of a fixed habit strength under increasing amounts of drive. From Figure 56, p. 246, of Hull, C.L., (1943), *The Principles of Behavior*. New York: Appleton–Century–Crofts.

Hull derived six corollaries from the primary predictive formula expressive of Postulate 4. For illustrative purposes two of these will be discussed.

> Corollary I states: When habit strength ($_{S}H_{R}$) is zero, reaction evocation potential ($_{S}E_{R}$) is zero.

> Corollary II states: When primary drive strength (D) is zero, reaction evocation potential ($_{S}E_{R}$) has an appreciable but low positive value which is a positive growth function of the number of reinforcements.

Both corollaries, Hull states, agree with the experimental data. In short, if an animal has never learned to run down a straight alley where food has been placed in the goal box, it will not do so when placed in one no matter how hungry it is. On the other hand, if an animal has had previous experience in running down an alley with food presented at the other end, it will continue to do so, at a slower speed, even though it is not at all hungry. Hull is able to develop several such precise predictions so that the validity of his total postulate system can be examined directly through experimentation. Each postulate gains an increment of support as each prediction, such as those of Corollaries I and II above, is verified by experiment.

The system seemed so promising that Dollard and Miller sought to apply Hull's basic behavior principles to Freud's personality theory. In 1950 Dollard and Miller published what is perhaps the major attempt to fuse the systems of Pavlov and Freud with that of Hull. Their *Personality and Psychotherapy* was a self-stated attempt to "aid in the creation of a psychological base for a general science of human behavior." More directly, their purpose was to apply both Hull's principles of learning and the axiomatic method to Freud's insightful but unstructured suppositions on the nature of human personality formation. Their specific belief was that the orderly processes of science as realized through the axiomatic arrangements of principles and observations allow for the production of new insights through the derivations made possible by axiomatic arrangements of principles. This approach required that Freud's tenets be translated into Hull's principles on the grounds that Hull's concepts were more easily verified by experimental demonstration than Freud's. Dollard and Miller narrowed their focus in reconstructing Freud to the issues of neurosis and its attendant psychotherapy. They listed eight major principles:

> 1. The principle of reinforcement was substituted for Freud's pleasure principle (the primary behavior of the id).

The pleasure principle implied that an organism had a genetically given tendency to move directly toward certain objects and consume them. These tendencies we know as hunger, thirst, sexual interest etc. By substituting the concept of reinforcement for pleasure principle, this response tendency, whenever it occurs, becomes quantifiable and, therefore, subject to experimental manipulation. This in turn would presumably allow the re-structuring of the original idea of pleasure principle into the axiomatic Hullian form.

2. Ego (ego strength) is defined as (a) the initial phase of the higher mental processes and (b) the description of culturally valuable, learned drives and skills.

Here Dollard and Miller are less precise in their translation of Freudian ego to Hullian terms than they were in translating the pleasure principle to the terms of reinforcement. Ego can refer to a learned drive or a skill, both of which can encompass very different kinds of behavior.

3. Repression is described as the inhibition of the cue-producing responses which mediate thinking and reasoning.

Repression can involve experiences that were never verbalized, as those of young children, or can involve experiences which were fearful enough so that the individual cannot remember them and, therefore, cannot speak about them.

4. Transference is a special case of the wider concept of generalization.

Because intense emotional responses can occur in therapy in the presence of the therapist acting as an agent, emotional conditions can be generalized to the actual therapist. If these emotional responses are reinforcing to the patient, as in the relief of stress, the generalization to the therapist is positive.

5. Conflict behavior occurs when two or more strong drives are operating and producing incompatible responses.

Conflict generally takes the form of not knowing whether to engage in or to move away from another person or process. Approaching and engaging in conversation with a member of the opposite sex can be seen as highly desirable while at the same time it may be seen as a potentially punishing situation because of possible rejection by the person approached.

6. Reinforcement of desired responses, although begun in therapy, requires real life experiences involving appropriate reinforcement as well.

This is a question of requiring the context for a generalized set of responses, learned within therapy to be applicable to similar situations the patient encounters in his or her daily life.

7. "Reality" is conceived of as the physical and social conditions of learning.

Dollard and Miller confirm the idea that behavior theory can provide the principles of behavior change while sociology and social anthropology need to provide a systematic treatment of relevant social conditions.

> 8. Repression and suppression are translated into the behavioral terms of inhibition and restraint.

Both learned inhibition and reactive inhibition were concepts used directly by Hull in his behavior theory. Learned inhibition refers to the process by which a habit is unexpressed because another stronger one or one under stronger drive conditions (D) interferes with it. Restraint refers more to a habit voluntarily eliminated by the individual (refers only to human beings) at a particular time in a particular setting.

With these translations of some of Freud's concepts into those of Hull, Dollard and Miller proceeded to analyze neurosis or learned conflict, repression and the unconscious, with the goal of developing therapy or a relearning process necessary to relieve the debilitating symptoms accompanying these learned problems. The therapist's principal activity, according to Dollard and Miller, is to aid the patient in discriminating those classes of stimuli toward which the expression of various strong emotions is appropriate and those classes of stimuli toward which it is inappropriate. For example, anger toward someone who has repeatedly harmed you is appropriate, but anger generalized toward other people who remind you of that person is not. The extent of the generalization is the extent to which the patient has become neurotic, a term generously used by Dollard and Miller in 1950 although considered archaic by most contemporary clinical psychologists.

Whatever similarity there may be among Freud's and Hull's concepts, Dollard and Miller's presentation is different from Hull's as it appears in *Principles of Behavior* in that no formal postulates are presented and there is no attempt to cast the various principles in mathematico–symbolic form. Dollard and Miller's discussion of the various issues is more similar to those of a traditional presentation made by a contemporary personality theorist of that era than it is to Hull's more precise style. Their consistent effort to establish the relationship among many of Freud's and Hull's ideas is convincing. However, Freudian criticism of Dollard and Miller was rapidly forthcoming. Freudians indicated that the core of psychoanalysis required a conscious conceptual restructuring of the patient's awareness of his or her personal history as well as a reformation of emotional responses to this history. Merleau–Ponty (1963) and others were to take psychoanalysis as a demonstration of the centrality of lived experience in the formation of personality. This contrasted with the reinforcement and drive concepts emphasized by Dollard and Miller. Other assaults on Hull's system and its application to many psychological issues in addition to personality formation and psychotherapy were to be made in the years following the publication of *Principles of Behavior.*

Of all the sixteen postulates, Postulate 4 was the one that captured the imagination of many psychologists. A great deal of research both by psychologists who regarded themselves as Hullians and by those who did not was directed toward examining its implications (e.g., Berlyne, 1950; Dollard and Miller, 1950; Harlow, 1950; Montgomery, 1953, 1954).

Generally, because of the clarity made possible by the axiomatic approach to theory construction within whose framework Hull stated the tenets of his system, the process of refutation was as accessible as that of confirmation. Consequently, although experimental data cited by Hull were used to construct postulates and were, obviously, supportive of them, other experimenters began to collect data which seemingly contradicted predictions made from the various postulates and corollaries. The immediately discovered weaknesses in Hull's system had less to do with his axiomatic approach than it did with the empirical content of the postulates — particularly Postulate 4, which eventually came under some telling criticism. K.C. Montgomery (1953) placed rats sated with food, water, and physical activity in a "Y" maze, one arm of which ended in a cul de sac and the other of which opened into a multi-alleyed Dashiell-type maze. The animals consistently chose the D-arm over the arm leading to the cul de sac. Montgomery concluded that an independent primary exploratory drive existed with the same ontological status as that of the more obviously physiologically linked primary drives such as hunger and thirst, and that this exploratory drive was reduced by continued exposure to novel stimuli. A controversy arose as to whether or not an exploratory drive increased as a result of conditions internal to an animal or whether it arose as a result of exposure to novel stimuli. By 1954 Montgomery's position changed and he rejected Hull's idea of drive reduction when the so-called exploratory drive was operating. Montgomery substituted the idea of "drive increase" for drive reduction as the essential mechanism involved in learning associated with exploratory drive which he considered external and, therefore, which would increase with exposure to novel stimuli. Whether or not his experiment with the Y-maze clearly differentiated between his and Hull's interpretations of the nature of drive, however, remained problematic. Montgomery believed that the drive-reduction hypothesis would predict that ". . . the animals should learn to enter the blind alley of the Y because continued exposure to that arm produces an appreciable decrease in the strength of the exploratory drive it evokes originally" (Montgomery, 1954, p. 60). However, Montgomery's logic is less than compelling. Presumably continued exposure to the Dashiell arm of the maze will also produce an appreciable decrease in the strength of the exploratory drive which *it evoked* originally.

The greater amount of novel stimulation provided by the Dashiell arm compared to the blind alley arm could also have elicited a greater amount of exploratory drive (Lana, 1960, 1962). If an animal were to choose the Dashiell arm initially and thus mediate an increase in exploratory drive, assuming that exploratory behavior occurs concomitantly, then it would follow from the drive-reduction hypothesis that the animal would choose the D-arm on future trials because this exposure to it would reduce the originally elicited drive to a greater degree than choosing the blind alley arm. Nevertheless, Montgomery's work and others' (Berlyne, 1950; Myers and Miller, 1954) were the opening salvos in the attack that would eventually tumble the drive-reduction hypothesis and thus render most of Hull's system inadequate in accounting for the animal behavior it purported to explain.

The idea that drive increase might be as compelling a factor as drive decrease in explaining the acquisition of a response set the issue for the next phase of research. Harlow (1950), working with rhesus monkeys, spoke of a manipulation drive which, like exploratory drive, operated on a drive-increase principle. In an early experiment Harlow used two rhesus monkeys and a six device mechanical puzzle which could be manipulated by hand. He showed that the animals increased the frequency of manipulation of the devices over 100 trials and that the number of errors decreased. Harlow and McClearn (1954) also presented pairs of different colored screws to monkeys such that the incorrectly chosen screw was not removable from a board while the correctly chosen screw was removable. Over a four day period the animals were able to remove the correct screw with fewer and fewer errors without any other drive (such as hunger, thirst, etc.) operating except the postulated manipulation drive. In both experiments no satiation of the presumed drive was evident. Primary drives such as hunger and thirst are susceptible to satiation within relatively short experimental periods. Harlow continued the line of experimentation with similar results, all of which cast doubt on the generality of the drive-reduction idea. In short, there seemed to be circumstances that resulted in an animal seeking out stimulation rather than attempting to eliminate it as Hull had predicted. Since Montgomery's and Harlow's research was done on nonhuman animals, the impression began to form among psychologists that because Hull's idea of drive reduction was inadequate to explain basic animal learning, it certainly was not applicable to human behavior change.

In addition, Hull, apparently without noticing, introduced a significant degree of uncertainty into the process of empirically validating the testable derivations of his axiomatic system. Instead of experimentally controlling all relevant variables operating on a single organism and then testing for changes in the dependent variable, he and his students experimented on a number of rats exposed to the same conditions with the assumption that all uncontrolled values of the various independent variables would "average out" and the mean value of the dependent variable would thus represent a reasonably accurate assessment. This approach, of course, contrasts with various classical axiomatic approaches in physics and chemistry in which there is an effort to experimentally measure and control all relative independent conditions in the experimental situation. Consequently, psychology's first systematic approaches to the axiomatic method had already departed significantly from the same approaches in physics and chemistry.

The demise of Hull's behavior theory more or less coincided with the rise of Skinner's. The failure of Hull's system based upon its inability to successfully predict behavior associated with drive increase also put an end to psychologists' attempts to construct formal, axiomatic theories of behavior. Hull's effort was seen as "premature" although his goal was acceptable to some (e.g., Spence, 1956). Skinner's (1950) main objection to axiomatic approaches to explain behavior was that they are mediational. That is, the formally or informally presented theorems of the system contained terms that identified variables that were not defined by observable events occurring either in the environment or in the organism. Physiological or psychological state variables such as "drive" or "anger" were used as integral parts of the system. Skinner argued that a statement made as part of an explanatory system needed to refer to something other than itself. To say that someone drinks because she is thirsty requires that "thirsty" refers to something other than drinking. If we mean that "thirsty" refers to unspecified physiological conditions of the organism then it behooves us to specify those conditions. In Hull's system, although ${}_{S}H_{R}$ was operationally defined as increasing as the number of trials in the learning situation increased, Hull indicated that the term also referred to an unspecified condition in the central nervous system. Similarly, drive, defined variously as hours of deprivation from food or water, or number and amount of shock, etc., also referred to activation mechanisms operating in the central nervous system. These mechanisms, however, did not form part of Hull's behavior theory. Skinner, of course, never denied the existence of physiological processes that participate in the maintenance of behavior acquisition. Rather, his point was that the postulation of such processes added nothing to our understanding within the context of Hull's or anyone else's explanation of the facts concerning behavior. A behavior system, he argued, should be precisely that — the designation of the various connections existing between behavior and the environment of the organism.

Variables presumed to mediate between behavior and environment postulated by thinkers such as Freud and Hull did little to advance our understanding of the nature of systematic human behavior change. Indeed, for Skinner they served to confuse rather than to enlighten. This rather straightforward proposition has been misinterpreted perhaps more than any other in modern psychology. Skinner did not deny the validity of the facts of physiology, clinical, developmental, or social psychology in helping to understand the nature of human activity. What he required was that all terms and propositions of explanation be usable. That is, saying that someone drinks because she is thirsty does not expand our knowledge of drinking. However, saying that after I observe a person eating large quantities of salted peanuts I have also observed that person consuming large quantities of water, gives us information we can use in influencing drinking. The establishment of functional relationships among response and environmental variables sometimes allows for consistently successful predictions without invoking mediating variables that serve no useful purpose either from a predictive or a theoretical perspective. Skinner also believed that it was possible to precisely control the independent variables operating in the acquisition of behavior. If this could be accomplished, there would be no need to run multiple animals through the same procedure, as Hull did, in order to obtain an average score for the dependent variable. This issue will be discussed below.

Explanation in B.F. Skinner's Behavioral Analysis

Skinner never explicitly embraced the axiomatic in forming his conceptions of the nature of behavior acquisition. Indeed, the axiomatic idea itself is regarded with suspicion by many of his followers. However, it appears that Skinner's approach to understanding the nature of animal activity yielded a coherent set of integrated principles, which suggests the possibility that some of his discoveries can take an axiomatic form. The basic schedules of reinforcement continuously established by Skinner and his co-workers from the 1930's to the present can be arranged in an axiomatic sequence. *Schedules of Reinforcement* (Ferster and Skinner), published in 1957, allows such an arrangement. An axiomatic arrangement of the principles of behavior change implied in the four basic schedules of reinforcement follows. There are a number of variations and combinations of these four basic schedules, however, they will serve to illustrate the axiomatic possibilities in Skinner's system.

General Definitions

1. Response: A specified behavior emitted by an organism within an environmental context or in the presence of particular stimuli.

2. Reinforcement: An event following a response which increases the probability of that response when that context reoccurs.

3. Extinction: The condition where no responses are reinforced.

The Schedules of Reinforcement

Fixed Ratio (FRa)

Postulate I

A response is reinforced upon completion of a fixed number of responses counted from the preceding reinforcement. Ratio refers to the number of reinforced responses (r) to the number of responses (R). Thus, FRa = (r/R) X 100.

Corollary I

The higher the rate at which the responses required for reinforcement are emitted, the shorter the time to reinforcement and, therefore, the higher the frequency of reinforcement. If r increases and t (time since last reinforcement) decreases, r per unit of time increases.

Corollary II

The reinforcement itself (e.g., ingestion of food and the stimuli associated with it) bears a constant relationship to the next reinforcement in a sequence of reinforcements. A common effect is for the animal to exhibit a reduced rate of responding just after reinforcement. Thus r/R = C (a constant) for the next reinforcement in the sequence.

Theorem I

A response cannot be reinforced within a shorter period of time than that required to establish the highest (FRa = 100) ratio of reinforcement. When t is minimal then r/R X 100 = 100.

Fixed Interval (FI)

Postulate II

A response is reinforced after a specified interval of time from the previous reinforcement. Thus, FI = r/t X 100.

Corollary III

A fixed ratio (FRa) schedule of reinforcement increases the number of instances where a reinforced response is immediately preceded by another response or group of responses rather than by a pause. This results in a differential reinforcement of high rates (Postulate I, Corollary I above). With a fixed interval schedule, time itself functions as a discriminative stimulus. There are pauses after reinforcement with subsequently accelerating rates, to the extent of even overriding the differential reinforcement of pausing that is still present. In the fixed ratio case, it appears that it is mainly the reinforcer without a time component that functions as the discriminandum.

Variable Ratio (VRa)

Postulate III

A response is reinforced according to a random series of ratios with an established mean between 0 (extinction) and 100 (continuous reinforcement).

$$\frac{r/R \text{ X } 100}{n_r/R}$$

where n_r = number of ratios in the sequence.

Corollary IV

There is a threshold of response such that, should a ratio of reinforcement approach zero, the response will be extinguished depending upon the species being reinforced. This corollary also holds for all schedules.

Variable Interval (VI)

Postulate IV

A response is reinforced according to a random series of ratios of time intervals since last reinforcement with an established mean. Responses after pauses are differentially reinforced, while rate of responding has little effect on rate of reinforcement. Therefore, the longer the interval since the last response, the more likely the next response is to be reinforced. Thus when t increases, r increases.

$$\text{Thus VI} = \sum_{n}^{x=1} \frac{(r/t)}{(R/t)} \text{ X } 100.$$

The Matching Law (ML)

In 1961 Richard Herrnstein sought to place the idea of the reinforcement of responses into an animal's natural context. He ran a number of experiments, as did other behavior analysts, which allowed him to reflect the usually complicated reinforcement context of animals in their natural habitat.

Postulate V

A response is a function of the reinforcement contingent on that behavior and of other reinforcements present at the same time as well as reinforcement contingent on other behavior and on reinforcement not contingent on any behavior (McDowell, 1988). Thus:

$$R = \frac{kr}{r + r_e}$$

Where R is the rate of responding, r is the rate of reinforcement contingent on the responding, r_e is the rate of reinforcement contingent on other behavior at the time of the response, and k is the rate of reinforced responding plus the rate of responding (r_e) reinforced by other behavior at the time of responding. k and r_e are parameters of the hyperbola produced by the matching law equation. Generally stating the matching equation, we may say behavior is distributed across an animal's available response alternatives in the same proportion as reinforcement is distributed across those alternatives (McDowell, 1988). Notice that if extraneous reinforcement (r_e) is small the rate of responding (R) will be large, and if r_e is large, R will be small. In short, extraneous reinforcement present at the time a reinforced response is occurring will interfere with the speed of acquisition to asymptote of the reinforced response. Since in a natural setting other behaviors, reinforced or not, are frequently present during the acquisition of a reinforced response, Herrnstein's experiments demonstrating the quantitative relations among response and reinforcement were crucial in meaningfully extending the general idea of the schedules of reinforcement.

The above postulates, corollaries, and theorems are not necessarily complete. Others can be made as well. For example, casting the differences between positive and negative reinforcement and positive and negative punishment in axiomatic form is an alternative which may actually be more fundamental to the behavior analytic program than beginning with the schedules of reinforcement. In any case, the intent is to show that it is clearly possible to cast the basic tenets of behavior analysis into axiomatic form which indicates that the various statements have similar epistemological status to those of both the earlier Hullian system and to the early explanations of the nature of movement of objects (Galileo–Newton) and of gases (Boyle). The axioms of the nature of reinforcement have held remarkably well since they were first articulated in the 1930's and semi-formalized in 1957 by Ferster and Skinner. Much nonhuman animal behavior is predictable from the schedules, especially if a human observer is able to set them. In their natural habitat, careful observation often, but not always, allows one to reconstruct how a schedule of reinforcement occurred in the natural environment of the animal. For example, in observing the behavior of a squirrel exploring a "squirrel proof" bird feeder which I had placed in my backyard, I noticed that it had solved the problem of obtaining bird seed. The feeder was built so that the weight of the squirrel distributed on a platform lowered a sheet of metal over the seed thus preventing the squirrel from feeding. The weight of much lighter birds on the platform was not sufficient to lower it and hence the seeds remained accessible. Although directly unsuccessful in obtaining seeds, the squirrel frequented the platform because the birds dislodged some seeds from the feeding receptacle on to the platform. Upon consuming these, the squirrel moved over various parts of the feeder in an apparent attempt to obtain more seeds. In so doing, it put a good bit of its weight on a small strip of metal not directly connected to the action of the platform. This weight shift raised the platform slightly and the animal was able to scoop a few seeds from the ordinarily closed food tray. In no time at all, the squirrel rhythmically shifted its weight to the metal strip, scooped seeds, ate, then shifted its weight again, scooped seeds etc. It seemed to me a clear case of the acquisition of an operant response without the interference of any human being, and that this process most likely occurs many times in the life of animals in the wild. In short the animal's initial shifting of weight to the strip of metal was accidental or a random move made in its general exploration for food which it could probably smell and which rested just under the platform. This particular movement was reinforced by the appearance of the seeds and their subsequent ingestion by the animal. Of course, another, more cognitive explanation is possible and indeed had been suggested in the 1930's by Tolman. The squirrel could have solved the problem of obtaining the seeds by thinking about it. It could have cognitively linked the various elements of its behavior to conclude, as a human being might have, that its appropriate behavior should be putting most of its weight on the strip that did not function in lowering the platform. There is no way to disprove this explanation. However, given that squirrels are most likely not capable of the same or similar symbolic behavior as human beings, the more parsimonious and likely explanation is the one attributing an operant sequence resulting in the squirrel's success in obtaining the seeds. However, it is important to indicate that current animal cognitive psychologists such as Amsel (1989) and Kendrick, Rilling, and Denny (1986) have continued to interpret certain animal behavior from a Tolmanian cognitive perspective.

The schedules of reinforcement operating in animal behavior are clearly demonstrable under laboratory conditions and sometimes through observation of the animal in its natural habitat. However, it is more difficult to demonstrate the same phenomena in human beings by experimental manipulation except in relatively trivial situations. Post hoc explanations of reinforcement sequences are usually necessary when speaking of human behavior.

Even though there are occasional situations such as casino gambling where someone will continue to play based on aperiodic reinforcement, the explanation of human behavior by reference to operant conditioning is largely interpretative. This, of course, is true for virtually all explanations of human behavior except, perhaps, those based on direct peripheral or central nervous system stimulation. Much explanation is necessarily interpretative for basically two reasons. The first involves the ethics of controlling the various influences on a person over a relatively long period of time in order to systematically apply diverse schedules of reinforcement to various behavioral sequences. In addition, when current behavior is of interest, neither the observer nor the subject under examination can ever be certain of the past history of reinforcement which presumably preceded the acquisition of the responses of interest. These restrictions, and others to be discussed later, separated psychologists into at least two camps: those who believed that the clarity and accessibility of the behavior analytic position based upon the schedules of reinforcement was the theoretical context that would produce the most success in psychological inquiry, and those who believed that any success behavior analysis might enjoy was restricted to animals, and some rather simple human behavior. Even the early behavior analysts never really attempted to construct an axiomatic system since their research indicated a behavioral complexity even in nonhuman animals which, they concluded, made axiomatization premature.

Nevertheless, many attempts by psychologists to explain some aspect of human or animal behavior take the form similar to that of building an axiomatic system. The resulting systems of explanation, however, are at best soft attempts at axiomatization. The countless numbers of masters and doctoral dissertations produced in psychology graduate programs are usually structured by rather formally stated hypotheses which are logically and empirically related to one another. Many of these hypotheses are not supported by the resulting experimental data and tentative conclusions are drawn as to the usefulness of the hypotheses in explaining behavior. Psychologists, it seems, would like to produce solid hypotheses that can be melded into a successful theory, if their doctoral dissertations are any indication, but the development of formal psychological theory has not proven to be a highly successful enterprise. We have discovered that experimental control is elusive. Psychologists' first response to that realization was to substitute statistical for experimental control, or at least to combine the two.

Quasi-Axiomatic and Correlational Approaches

Once the testing of hypotheses is accomplished by referring to probability data, the hope of developing an axiomatic system to explain the behavior in question is weakened. We have seen that even Hull, who wrote the first formal psychological theory, depended on averages gleaned from running several animals under the same conditions through runways in order to account for non-experimentally controlled characteristics such as different running speed, intelligence, etc. Psychologists have accepted their limited ability to control key independent variables in a single organism and have instead relied on probability assessment. One theoretical exception to this position is, of course, that of the behavior analysts who emphasize single organism experimental control in research on nonhuman animals.

The analysis of variance and its derivatives entered the psychologist's research armementarium largely through the work of the American mathematical statistician G. W. Snedecor, the interpreter of R.A. Fisher. Some of Snedecor's empirical interests were agricultural and experiments in that area were aided by application of the analysis of variance. Psychologists quickly took to the technique as one that was useful in coming to a decision about null hypotheses. Psychological research in the 1940's and continuing to the present has been replete with data handled by one of the levels of ANOVA. Since null hypothesis significance testing required a dichotomous decision, the setting of a probability level for the F-ratio further reduced the accuracy of the decision by underutilizing the data that were collected during the course of the experiment. That is, even though a distinct relationship may have existed between the dependent variable and any particular independent variable, if there was not sufficient power to detect the obtained effect, a decision not to reject the null hypothesis followed and, therefore, also the rejection of the experimental or so-called alternative (to the null) hypothesis. In the last several years, researchers have been sensitized to the problem of assessing power by, among others, Cohen (1965, 1988, 1994), Rosenthal and Rosnow (1991), and Rosenthal and Rubin (1982, 1985).

A technique was needed that would allow for the direct assessment of the effect of an independent variable on the dependent variable. By calculating the correlation between group membership and scores on the dependent variable the degree of relationship is assessed directly and the numerical value of the relationship is, of course, expressed as a number lying between −1 and +1. Contrast analysis focuses the search for differences among the experimental groups in a precise manner which is not the case with an omnibus test such as F with the degrees of freedom in the numerator being greater than one (see Rosnow, Rosenthal, and Rubin, 2000, for details).

However, others (e.g., Chow, 1988, 1996) have argued that a significance test has frequently been used in psychological research because of the psychologist's desire to proceed scientifically at a level of abstraction that is different from that made possible by the use of effect size or contrast analysis. Chow argues for an hypothesis-testing approach which is a hold-over from the classical approach to theory building of the axiomatic systems of early physics and chemistry. The null hypothesis is specifically tested as part of those psychological research designs that assume, usually tacitly, that it is possible to build an axiomatic system of explanation regarding the data in question. Null hypothesis testing is consistent with the *modus tollens* procedure.

Chow (1988) describes the hypothesis-testing sequence as follows: if the major premise is, If A_1I_n (the alternative hypothesis, I_n being one implication of A_1, the set of auxiliary assumptions underlying the experiment) then T_1 (a theory) is under EFG (the control and independent variables of the experiment). The minor premise is: D (the experimental outcome) is dissimilar to X (the experimental expectation). If the experimental conclusion that A_1I_n is false (the null hypothesis) is accepted, then T_1 is false. If A_1I_n is true (alternative hypothesis) then T_1 is probably true. This sequence actually involves both *modus ponens*, in the major premise, and *modus tollens*. Reversing the expectations of the minor premise (D is similar to X), the experimental conclusion (A_1I_n is probably true), and the theoretical conclusion (T_1 is probably true) provides us with the substance of the alternative (to the null) hypothesis. Chow continues his analysis by differentiating descriptive research, that he identifies with the effect size and contrast analyses that seek to estimate appropriate population parameters, and theory-corroborative research which is established by the use of *modus tollens* (and *modus ponens*). However, it is not difficult to establish *modus ponens* and *modus tollens* within a parameter estimate framework as with the proposition, If A is probably greater than B and B is probably greater than C, then A is probably greater than C and so forth, consistent with *modus ponens*. This leaves us with the same difficulty described above that neither the null hypothesis-testing approach nor the parameter-assessment approach allow us to conclude with certainty that a theoretical statement is true or false simply because both are intrinsically probability statements which address issues which are intrinsically probabilistic. Unless there is the possibility of controlling the relevant independent variables in an experiment on single subjects, the classical axiomatic, theory confirming procedure is unavailable or must be modified in significant ways. In the earlier axiomatically developed and well-established theories of Newtonian physics and of chemistry any departure from certainty, that is, a probability of 1.00 associated with any prediction derived from the postulates, is considered an aberration due to faulty measurement techniques rather than to uncertainty inherent in the predictive statement or the postulate from which it was derived. In psychology we often think of the data under examination to be inherently changeable as when attitudes are formed and altered over time. This issue will be discussed more fully in later chapters.

In short, utilizing an effect size analysis, as is the trend in contemporary experimental psychology, indicates another step in the abandonment of the classic axiomatic procedure in theory building. As suggested above, the use of statistical techniques in order to examine the effects of independent variables in an experimental situation departs from the early physical and chemical models of directly controlling variation within the confines of the experiment. With Hull's use of averages to summarize subject performance, axiomatic theory building was partially compromised. Aside from the behavior analytic return to experimentally controlling the individual organism, the great majority of psychologists have depended upon statistical control in their experiments. The virtually ubiquitous use in psychology of the formation of experimental hypotheses which are tested against the null indicates that the shell of the axiomatic approach to theory has been maintained without its essential core. The recent recognition by Cohen (1965, 1988, 1994) and others of the need to use confidence intervals in place of the directly tested null hypothesis, can be taken to be at least a tacit recognition that psychological theory can not be built by an axiomatic approach. In general, psychologists make inferences from samples to populations rather than from the single case to the generic. Data accumulation implicitly follows the idea that probability is paramount when assessing the validity of concepts used to explain (especially) social phenomena.

It is, of course, possible to construct an axiomatic system of explanation utilizing probability data as, for example, in physics where a highly predictable statistical distribution is obtained when photons are passed through a series of baffles and register on a photosensitive screen. Psychological theory, however, has continued the demise of the axiomatic as found potentially in Freud and actually in Hull and Skinner. There is a near absence today of any attempt to build encompassing theories of animal or human activity, nor is there any attempt to use a formal axiomatic system in building theories which address even highly circumscribed phenomena.

Hermeneutics

Originally, hermeneutics referred to the methodological principles of the interpretation of ancient texts, particularly the Bible. By the late nineteenth century Dilthey (1924–1927/1977) and others redirected hermeneutical analysis to interpreting the nature of human reality in historical time. The goal of hermeneutics was different from, and even opposed to, the systematic examination implied by science. The method of science seeks to eliminate all interpretation and to substitute for it the single precise formulation which eliminates all others. The implication is that science is incapable of successfully explaining certain kinds of human activity and, as a result, interpretation of the nature of that activity using hermeneutical principles is necessary to gain any understanding at all. What is at stake is the meaning of the history of humanity. There are two general types of hermeneutical analysis: (a) the grammatical interpretation of a text or a phase of human history which is based on discourse that is common to a culture or an individual, or (b) interpretation that is addressed to the singularity of the individual (e.g., a writer if a text is involved). Therefore, the scientific enterprise, involving as it does a special, non natural language, is not and can not be, hermeneutical. Causal analysis of the scientific type does not penetrate the content of social history as it does its manner of acquisition. Historical content is understood by reference to its context and what a group or individual values and interprets within that context. Interpretations developed from hermeneutical analysis reverse the process of science by attempting to grasp the intentional quality of individual or group life experiences. This is not to say that hermeneutical analysis may be irrational or inconsistent with careful observation. On the contrary, the rules of rational discourse and objective observation are of critical importance. However, since such analysis is directed only to the human world and not the physical or nonhuman animal worlds, even the apparently irrational reactions of social groups are significant in hermeneutical analysis. In the later discussion of the concepts of deconstruction as they have influenced social psychological explanation, the relevance of the hermeneutical approach will become apparent.