Chapter 6

CLARK L. HULL: PHYSICAL BEHAVIORISM

BIOGRAPHY

By his own account (1952a), Clark Leonard Hull was born in a log house on a farm near Akron, New York, in 1884. He graduated from the University of Michigan and taught at a normal school in Richmond, Kentucky, where his load of twenty classes a week did not stop him from beginning the research that would constitute his doctoral thesis. He did his graduate work at the University of Wisconsin, where he subsequently joined the faculty. The most striking aspects of Hull were his ingenuity, his adaptability, and his ambition to become a leader in his field. The latter goal was certainly accomplished; although he died in 1952, his imprint is clear not only in the psychology of learning, but in many other areas where his students and their students carry on work that shows Hull's unmistakable influence.

Hull's ingenuity was demonstrated early, when he first began doing his research at Wisconsin. He was interested in the evolution of concepts and designed and built a device that he called an automatic memory machine. Today, any psychologist interested in such things would be virtually helpless without a computer, and even the poorest researcher would seem better off than Hull, at that time. (Presumably, the facilities at Wisconsin are somewhat better now, despite budget constraints.) Here is Hull's description of his equipment:

> I designed and constructed with the few hand tools there available an automatic memory machine which I used throughout most of my dissertation experiment. The drum was made from a tomato can fitted with wooden heads. The automatic stepwise movement of the drum was controlled by a long pendulum; the coarse-toothed escapement wheel controlled by the pendulum was filed from a discarded bucksaw blade. . . . At that time a person with a little initiative could construct a useful behavior laboratory in a wilderness, given a few simple tools and materials; this is true to a considerable

FIGURE 6.1a Clark L. Hull, 1884–1952. *Photo courtesy of Clark University Press*

extent even now for a wide range of important experiments. (From Hull's autobiography, 1952a, pp. 148–149)

Hull seems to have been marvelously adaptive as well as ingenious. His first teaching at Wisconsin was in aptitude testing, a subject in which he was initially less than expert. But Hull did nothing halfway. He published his course materials in a book entitled *Aptitude Testing* (1928). But this was not to be his life's work:

> The survey leading to the publication of *Aptitude Testing* left me with a fairly pessimistic view as to the future of tests in this field, and I abandoned it permanently. (Hull, 1952a, p. 151)

He was then asked to participate in an introductory course of lectures for medical students. He felt that the general area of hypnosis and suggestibility was useful in medicine and so began studying what was known in the field and teaching it to his students. Over a period of ten years he and twenty students published 32 papers in that area, and in 1933 his book *Hypnosis and Suggestibility* was published.

Other work included a careful study of the effects of pipe smoking on mental and motor efficiency. An antitobacco group requested that he do such a study, and he conducted the experiment superbly. The results were published in 1924, although they were not what the sponsors had wanted.

In 1929, Hull's reputation as a researcher was such that he was invited to Yale to work as a research scientist in the Institute of Psychology, later incorporated into the Institute of Human Relations. As a research scientist, he had no teaching or administrative duties and was left free to devote all of his time to research.

When he arrived at Yale, he planned to carry on his work in hypnosis but was discouraged from doing so by opposition from the medical authorities there. Hull attributed their opposition to a superstitious fear that was not present in the midwest. He was encouraged to contribute toward the grand plan for the institute, which had gathered many psychologists, sociologists, cultural anthropologists, and others in making a unified and integrated contribution to the social-behavioral sciences. Hull (1952a) later wrote that such an enterprise is best carried out with leadership in the form of a scientific führer but that such a system runs counter to our democratic policies and would hamper creativity by the individual members. Evidently, enough of the participating scientists were brought to Hull's general point of view by occasionally attending his seminars that he became de facto director.

Hull was an exceedingly ambitious man (as was Thorndike) who decided as a young man that one must make one's great scientific contribution before the age of 40, since a study of the history of science showed that the greats, such as Berkeley and Newton, performed their major works while young. Unfortunately, Hull was beset with typhoid fever before going to college and crippled

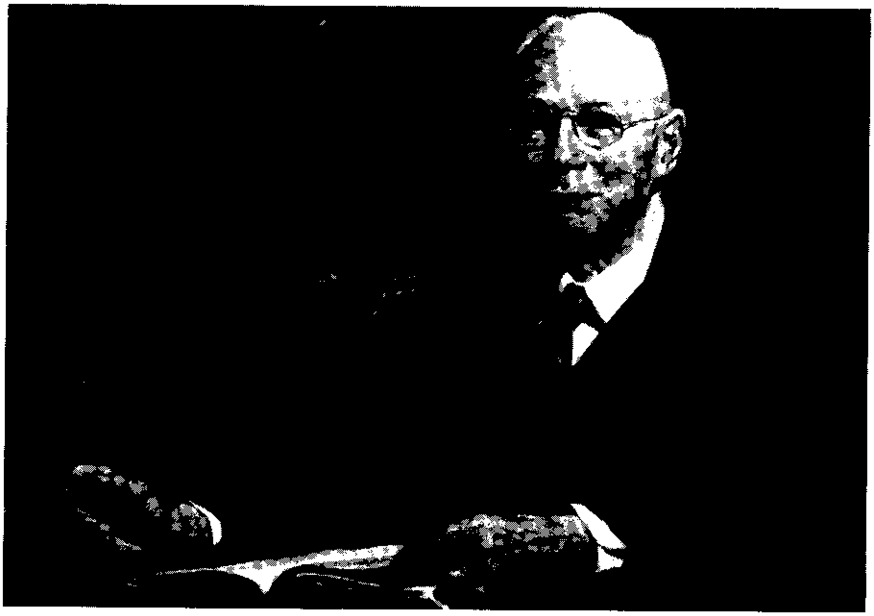


FIGURE 6.1b A painting of Hull in later life. *Courtesy of the Archives of the History of American Psychology*

with polio at the age of 24. Additionally, his eyes gave him great problems, so his mother had to read to him.

It was while recovering from the polio attack that he decided on experimental psychology as a life's work, and his reasons were these:

> What I really wanted was an occupation in a field related to philosophy in the sense of involving theory: one which was new enough to permit rapid growth so that a young man would not need to wait for his predecessors to die before his work could find recognition, and one which would provide an opportunity to design and work with automatic apparatus. (Hull, 1952a, p. 145)

Hull's conception of psychology and his hypothetico-deductive method seem to have caught on immediately. During the 1930s, Hull was able to attract some of the best students in the world to his laboratory at Yale. Students such as Kenneth Spence, Neal Miller, and O. H. Mowrer carried on what was essentially Hull's project (although each greatly helped shape it) for years after Hull's death in 1952. Hull was clearly the most influential psychologist of the 1940s and perhaps of the 1950s. His many students and their students are scattered through colleges and universities in the United States, and many of them are keeping Hull's way of looking at things alive (cf. Amsel & Rashotte, 1984). Hull's major publications are:

Principles of Behavior, 1943
Essentials of Behavior, 1951
A Behavior System, 1952

In addition to these books, Hull and his close collaborators published countless papers from 1920 to 1952. He did not become great by the age of 40—his health problems and other matters delayed the completion of his doctoral dissertation until he was 34. But he did have a research associateship at Yale by the age of 45 and, rereading the history of philosophy and science, he found that greatness was often attained with work done long after the age of 40, as with Locke and Kant.

INTRODUCTION

Section 1 of this chapter examines Hull's significance for psychology, both during the time he worked and during our time. He was influential beyond telling, and his theory set the standard for the psychology of a generation. In 1954 a group of eminent psychologists met at Harvard and evaluated the rival learning theories, as well as Hull's (Estes, Koch, MacCorquodale, Meehl, Mueller, Schoenfeld, & Verplanck, 1954). Significantly, the other theories were praised or condemned to the extent that they resembled Hull's!

Section 2 discusses the basics of the theory itself. Hull believed in the clear expression of the basics of one's theory and in the careful testing of the implications of the theory. We will consider the set of *postulates* presented in 1943, as well as the empirical support for them and the sorts of tests one might subject them to. This *postulate set* is really the core of the theory, and Hull's views on the importance of *drive* are worthy of special consideration.

We will also consider the general *hypothetico-deductive method* which he advocated and which lent great appeal to the theory. It seemed wonderful at the time to have a method that would keep us unerringly on the path toward truth, and this method seemed to do just that.

We will also see how Hull could ingeniously explain complex things as the action of a machine; he insisted that any explanation was complete only if we could build a device that would act as the explanation required. How can a machine show evidence of learning, knowledge, foresight, and anticipation? Hull proposed an answer.

Section 3 presents criticisms of Hull's theory. Critics such as Tolman had difficulty with Hull's view, since the theory seemed to work so well, even when it seemed preposterous on some points. Many critics (even Tolman, half-heartedly) gave up and either joined Hull's cause of threw in the towel. Hull's theory worked surprisingly well, and he was the establishment; it is always difficult to fight the establishment, especially when one loses battle after battle with it. Nonetheless, Hull's theory includes basic elements, both in its assumptions about psychology and in its views concerning the ways of doing research, that have been vigorously attacked by other psychologists.

Section 4 considers other aspects of Hull's theory. We will briefly discuss applications that he suggested and then consider the work of two notable collaborators. Spence worked with him for many years and made many contributions; we will see that the influence of Hull and Spence is still felt and acknowledged in current research in motivation (see McClelland, 1985). Neal Miller became a prolific researcher, and it is with Miller and Dollard (1941) that social learning theory began. We will point out clear parallels between this early work and the more recent work of Bandura, though the latter is often erroneously viewed as a follower of Skinner!

1. THE SIGNIFICANCE OF HULL'S WORK

In the 1920s psychology was changing; it seemed to many that progress was finally going to be made. The sterile research of the introspectionists, led by Titchener, was losing favor steadily. The functionalists were influential, though disorganized, and Freud's ideas were becoming well known. The Gestaltists had not yet arrived and Thorndike was gaining adherents. At the same time, Watson was loudly calling for a revolution in psychology, and Guthrie, Tolman, Kantor, and others were to join in essentially the same cause. Something was happening; it seemed at last that the scientific study of behavior and experience was to begin, but the movement lacked organization. Everyone opposed the introspectionists, but there was no clear and concrete plan as to how to proceed.

This is where Hull came in. He advocated the organizing of what everyone believed to be true (or roughly true) into a clear form, so that we knew where we were beginning. Then we could derive testable statements from these assumptions and carry out careful experiments to test them. Depending upon the results of the tests, we would modify the assumptions. Thus, our list of "truths" would change constantly and improve gradually. This self-correcting system had great appeal, especially at that time, when we knew that the field was going somewhere but that too many competing theories filled the air. Let us work together under a shared set of assumptions and progress together, rather than continue to compete in a disorganized fashion. Psychology was to be institutionalized and Hull was in a perfect position at Yale to direct such an undertaking.

His initial effort was aimed at accounting for animal behavior, and this was outlined in his *Principles of Behavior*, published in 1943. This was extended nine years later in *A Behavior System* (1952b). A third volume, intended to include human social behavior, was never written, owing to Hull's death. Nonetheless, he felt, as have many others, that the first two works included the essence of all that psychologists need know to study all behavior and experience.

The next section presents the essentials of Hull's theory, and the reader is reminded that his immense influence means that his theory is worthy of careful consideration. Its general assumptions are very much alive today.

2. BASICS OF HULL'S THEORY

Hull assumed three things concerning psychology and the method of doing science. First, he was convinced that an organism must be viewed as a biological machine, or *automaton*. When we get down to it, we are muscle, bone, blood, nerves, and visceral organs, and our explanation of our behavior and experience must not lose sight of that fact. Everything else, our mental life, our purposes, our insights, and so on are ultimately dependent upon the activities of the body. When we explain mental activity, we must do it in terms of bodily actions; as mentioned above, we explain a phenomenon only when we can build a device that operates in the way that we propose we do.

This led Hull to an exclusive emphasis on stimuli and responses. Stimuli are things that produce reactions, things that we can point to in the environment. Responses are the movements of muscles and the secretions of glands; we can also identify these, although in some instances it is difficult. All of our behavior and experience is understandable only when it is translated to stimulus-response terms. This is *S-R psychology* in its pure form; although it may be repugnant to view ourselves as S-R automata, it is difficult to argue that we are not. Biologists have long held this belief, and modern medicine, in large part, assumes that this is the case.

Hull's second assumption was that it is absolutely essential to quantify things, to measure and attach numbers to them. Much of his time was spent in assigning numbers to represent the amount of learning or the degree of motivation present under different conditions. He was a master at this and successfully predicted the results of many experiments, using trains of calculations that aroused the admiration of his followers and that confounded his critics. We will get a flavor of this in the following pages.

Thirdly, Hull emphasized the importance of clearly stating basic assumptions in a way that permitted testing of them. This was essential both to give order to the field and to act as a guide to research. A great many of Hull's followers were attracted because of the appeal of his hypothetico-deductive method. Psychological research often seems to lack direction, but in this case it seemed that a systematic undertaking was under way and that the guidelines were laid out in the *Principles of Behavior* (1943). Turn to any page of Hull's text and find a postulate or corollary, consider its consequences, and there is your experiment.

For example, suppose that one of the postulates says that when we learn something new, such as someone's name, all stimuli present at that time become connected to that name. We test this by putting ourselves in the presence of stimuli that were there at the time the name was learned. We find that some stimuli, such as the sight of the person whose name we have learned, the presence of others who were there at the time, or the room in which the learning took place bring the name to mind more readily than do other stimuli present, such as the clothes we were wearing. We modify the postulate to specify that other people and places are more closely associated with the response than are other stimuli, such as those provided by our clothes. If it is important, we can then continue to refine the class of stimuli that are most effective. We test successive hypotheses until we are satisfied that we know which of them will be effective. This is a difficult task, to be sure, but Hull believed that such an undertaking was the only way to progress toward an eventual understanding of what we do and when we do it. It was certainly slow, but it was certainly sure, and it was about time that psychology got on the sure path!

Hull's Postulates

Hull made every effort to be precise, for this reason:

> It is believed that a clear formulation, even if later found incorrect, will ultimately lead more quickly and easily to a correct formulation than will a pussyfooting statement which might be more difficult to convict of falsity. (1943, p. 398)

Only a clear statement may be tested through experimentation, and only through such tests are we able to determine whether our assumptions are correct. Statements such as the Gestaltists', which spoke of such things as "emergent properties," were too fuzzy to deal with; Hull (1943) referred to their viewpoint as a "doctrine of despair."

The postulates and their derived corollaries were meant to be as clear and testable as possible. The postulates were the principles from which one begins, and Hull's view of doing science emphasized the deductive method, widely used in the past by rationalists such as Descartes. According to Spence (1943), Hull adopted the hypothetico-deductive method after reading an impressive paper by Einstein in 1934. This was Hull's version of a theory, stated thus: "A theory is a systematic deductive derivation of the secondary principles of observable phenomena from a relatively small number of primary principles or postulates" (1943, p. 2). The object of theory, of course, is to explain, and this is Hull's opinion of the nature of explanation. An explanation is a "proposition logically derived from a set of definitions and postulates coupled with certain observed conditions antecedent to the event" (ibid., p. 23).

The 1943 postulate set was to serve as the starting point for research, and it proved a very influential guide for the research of the 1940s and 1950s. The set was altered somewhat, though not very drastically, in the 1952 system, and the heart of the system remained what it was in 1943. True followers of Hull ("Hullians," as they are still called) see the changes as much more major than an outsider would. We will concentrate on the 1943 set; for many years, they constituted Hull's theory.

Postulate I: The Stimulus Trace Stimuli acting on us are effective for a time after their removal. We are familiar with visual afterimages, as well as with the aftereffects of pressures on our skin and of loud sounds. Hull believed that the real stimulus was not the light or sound source, but the response of the nerves themselves. He used the lowercase *s* to refer to the activity of the nerve and capital *S* to represent the physical stimulus.

Postulate II: Afferent Interaction A gray patch on a blue background looks yellowish, whereas the same patch on a red background looks greenish. Stimulation is affected by other stimulation going on. A newly broken finger makes us forget a small bruise elsewhere that seemed so painful earlier. This postulate was meant to include everything that the Gestaltists were stressing, except for "emergent properties" or anything that Hull felt similarly mystical. Afferent interaction is represented by $\check{s}$.

Postulate III: Reflexes Present at Birth We come with a set of unlearned behaviors, evoked by certain kinds of stimulation. Hull saw these as unlearned S-R connections. These S-R connections are arranged so that a given form of stimulation first produces one innate response, and if that fails to remove the source of stimulation, other innate behaviors appear.

For example, suppose that a speck of dust enters the eye. We reflexively blink and tears flow. If the speck remains, we may blink more vigorously, rub our eyes, and do other things, all occurring automatically. Many reflexive behaviors are controlled by the spinal cord. If the cerebral cortex of an animal is removed, it is still possible to stimulate the animal's skin and to evoke stepping, walking, running, and galloping.

A sequence of stimuli and reflexive reactions occurs when we feed an infant. We may produce turning of the head and opening of the mouth by touching the infant's cheek. The milk entering the mouth produces reflex salivation, and the passage of the milk produces in turn swallowing, peristalsis, secretion of stomach juices, and absorption in the small intestine. The result of these and similar processes is survival.

Reflex behavior is typically produced when a primary need is present. This is a bodily condition that, if left unattended, threatens the life of the individual or the species. The following list was proposed by Hull to include the basic needs. These are the sources of all motivation:

hunger	temperature regulation	sleep
thirst	defecation	activity
air	urination	sex (nesting, care of young)
rest	tissue injury	

These needs produce movement, and movement continues until the need is removed. Hull believed that other motives are derived from biological needs; it may seem to us that most of what we do is motivated by somewhat more elegant needs. But, in fairness to Hull, we should note that it is such needs that certainly are the prime motives for virtually all animals and for the vast majority of the human population of the earth!

Postulate IV: Primary Reinforcement This is the most important postulate and deserves extended treatment. We do not seem to spend our lives reacting reflexively to a succession of needs; we change our behavior because new S-R connections are formed. Hull called such new connections *habits*, represented in his system by $_SH_R$. Habits are formed through the action of the law of effect. To illustrate the complexity of Hull's postulates, this is how postulate IV reads:

> Whenever an effector activity ($r \rightarrow R$) and a receptor activity ($S \rightarrow s$) occur in close temporal contiguity . . . , and this contiguity is closely associated with the diminution of a need . . . or with a stimulus which has been closely and consistently associated with the diminution of a need . . . , there will result an increment to a tendency ($\Delta_S H_R$) for that afferent impulse on that occasion to evoke that reaction. The increments from successive reactions summate in a manner which yields a combined habit strength ($_SH_R$) which is a simple positive growth function of the number of reinforcements. . . . The upper limit . . . 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 growth function of the delay . . . in reinforcement; [and so on]. (1943, p. 178)

What the postulate says is simply this: Whenever a response is made in the presence of a stimulus and that stimulus-and-response connection is closely followed by a decrease in a need, there will be an increase in the tendency of that stimulus to produce that response in the future. For example, suppose you are training your dog to come on command. You pair "come!" with the dog's movement toward you when you give it a piece of food, which diminishes a need if the dog is hungry.

How much of an increase in the tendency to come occurs with each piece of food given? It depends upon the amount of hunger and the amount of food given. The greater the need reduction, the greater the effect. The amount of need reduction depends both on the amount of need (hunger) and on the amount of food you give. The effect is greater as the delay between the behavior and the food lessens. Similarly, the effect is greater as the time between the command and the dog's action gets closer. To successfully train a dog to come (or to teach a child to read, or whatever), be certain that a need exists, whether it be hunger or a secondary need for praise, be certain that the consequence of the act reduces the need, ensure that the stimuli you want connected to the deed are present when the deed is done, and do not delay the consequence after the act occurs.

You will notice that Thorndike would not have disagreed with any of these stipulations and you may wonder what it is that Hull has added. Actually, this postulate only adds precision to the law of effect. Hull was dead serious when he proposed the equation below that allows the calculation of habit strength (the strength of the S-R connection), and he was a master at actually calculating habit strengths and showing that his predictions were accurate.

One simple equation for the calculation of habit strength appears in his *Essentials of Behavior* (1951):

$$\Delta_S H_R = F(M - {}_S H_R)$$

This means that the increase in habit strength on a given trial ($\Delta_S H_R$) is the product of a constant (F), which depends upon the situation, and the quantity *M* minus the current habit strength. *M* is the maximum habit strength, depending upon the degree of need and the reinforcer used. As training progresses, the quantity ($M - {}_S H_R$) decreases, since ${}_S H_R$ increases on each trial. Thus, the increments added to habit strength become less and less as training progresses. This accounts for the decrease in progress as we proceed. When we begin to learn a passage of poetry, for example, the amount we retain on the first reading is greater than that on the second, third, and fourth readings. Part of the reason for this decrease in progress, in Hull's view, was the fact that as we approach *M*, less is left to be learned and the equation shows that this leads to successively smaller increments in habit strength. This decrease in progress is apparent in Figure 6.2.

Note that postulate IV does not require that reduction of a real (primary) need occur in order for habit strength to increase. Hull (1943) specifies that a "stimulus which has been closely and consistently associated with the diminution of a need" works as well. Let us examine Hull's views of reinforcement in general, because that is what he is talking about in this postulate.

Hull viewed living things, including ourselves, as self-maintaining automatic machines. Our bodies have needs for nutrients, water, constant temperature, waste elimination, activity, sleep, and so on. The parts of our bodies that are not directly concerned with these things have evolved to support the organs so concerned. A muscle mounted on a skeleton is ultimately there to move us and move our limbs so that we can find and eat food, drink water, keep warm, and so on. The same muscle may aid in writing or painting, but that is not the reason for its evolution. We are, figuratively speaking, no more than "traveling stomachs."

We are born with reflexes that can maintain life if food and shelter are no problem. Typically they are not problematic for humans in the United States. But most living things cannot rely on reflexes for long; they have to seek nutrients and shelter and they must be able to learn to do so more efficiently as they grow older. How does such learning occur in a mechanical device? Postulate IV is Hull's answer.

The Importance of Primary Drive

The conception of humans and other animals as drive-animated, satiation-seeking automata is a very common view in psychology; Freud is probably the best-known proponent. To appreciate fully the reasoning upon which the conception is

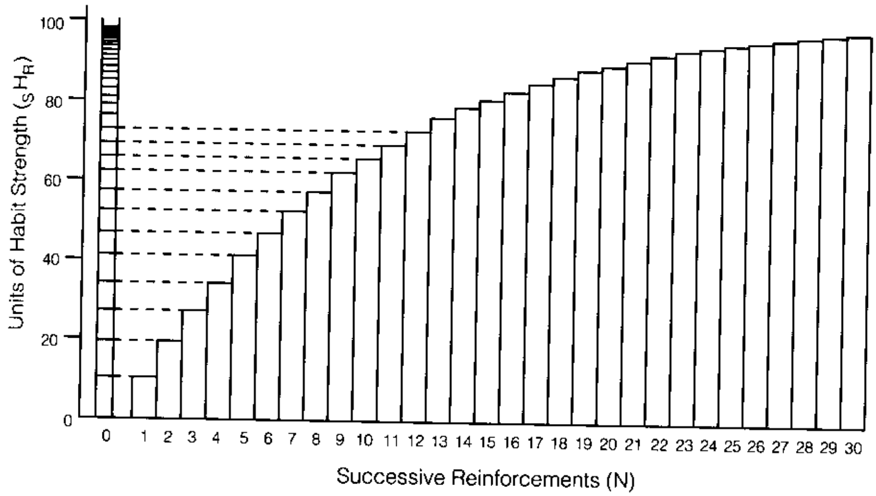


FIGURE 6.2 Growth in habit strength ($_SH_R$) as a function of number of reinforced trials (N). Notice that the increments added are progressively smaller.

based, we will consider some of the traditional evidence for the importance of biological drive in learning and motivation. Later in this chapter we will reconsider the evidence and examine counterevidence.

The General Argument Consider the argument. A cell alone in the wild takes in its nutrients, metabolizes them, excretes waste, and so on. In the course of evolution two cells join forces, with one responsible for locomotion and taking in nutrients and the other for metabolizing them and excreting waste. More cells join (in the course of evolution) and the duties are separated still further. Over the span of time, more and more specialization occurs until an organism develops that seems to bear no resemblance to the original cell. Yet, its functions are basically the same. It must take in food, metabolize it, and excrete wastes; if it fails in any of these functions, it dies. All of the many activities of living things are ultimately done to maintain the life of the individual; if we add sexual behavior, we include the perpetuation of the species as well.

Whatever thoughts and hopes and dreams you may have are possible only if the basic processes of life continue. You must be fed, watered, kept at a reasonable temperature, and so on. In current American society it is easy to lose sight of this fact, but for 99.9 percent of the living things on earth, motivation lies solely in keeping the basic life functions going. These basic needs are apparent to us when we are aroused; as the electric companies say, "Wait until the lights go out."

A malfunction of basic biological processes often leads to a deficit or an excess of needed materials (such as protein or oxygen) or a departure from some other norm, such as body temperature. Such a departure from normality constitutes a basic need, which usually energizes behavior. In so doing, basic needs act as basic drives. Walter B. Cannon showed in *The Wisdom of The Body* (1932) that the body is in large part a self-regulating system. (Claude Bernard had shown this long before.) Body monitors constantly keep track of levels of nutrients, blood pressure, blood gas levels, temperature, and so on and initiate corrective action if a departure from the homeostatic norm occurs. (Interestingly, this does not occur in the case of oxygen deprivation.) This is what is meant by drive and a large part of the body's work consists of reducing drives. But are drives the real basis for all motivation? Hull thought so. Look at the evidence.

Irrefutable "Evidence" for Drive as the Basis for All Motivation

The Few Motives of Infants Anyone who has had the most casual contact with infants must be struck by the simplicity of their motives. They need warmth, food, comfort, shiny objects, and little else. Henry Murray observed 100 Harvard students in 1938 and proposed the following list of viscerogenic motives, which happen to be the same motives of the infant. These are motives that we carry with us all of our lives. They express the need for:

air	lactation
water	heatavoidance
food	coldavoidance
urination	sentience (sensuous needs)
defecation	noxavoidance (avoidance of noxious events)
harmavoidance	
sex	

In addition to these primary needs, Murray and his group listed 28 psychogenic, or secondary, needs. These are the needs of adults and of older children and include needs regarding objects (for example, acquisition), achievement (for example, need for superiority), defence (for example, overcoming defeat), power (for example, need for dominance), affection (for example, need for affiliation), and social affairs (for example, the need to point and lecture).

Where do these secondary needs come from? Murray (1938) and countless others have suggested that they derive from the basic needs. The infant needs milk, which comes from the mother. This association of milk and mother makes the infant need its mother. Mother gives milk and other things when she is attending to the infant, so attention becomes something needed. Attention while praising the infant means that praise becomes a secondary need, and so on. How else could it be explained? The infant's motives are so few and ours are so many; thus, the many motives of the adult must develop from and ultimately depend upon the few motives of infancy. Freud's rendition was different only in particulars.

Specific Hungers A follower of Cannon, Curt Richter, was one of those responsible for the attention paid in the 1930s to the phenomenon of specific hungers. If a rat, child, or other organism is deprived of one of at least eleven nutrients (for example, calcium, milk protein, thiamin) the organism often selects foods rich in the missing nutrient to remedy its deficiency. This seems powerful evidence for the influence of biological drive. The body detects the deficiency and promotes action to remedy it, presumably by sensitizing the taste preferences of the affected organism.

Separation of Drive and Learning Hull believed that learning (${}_SH_R$) and motivation (D) had separable effects. The key evidence for this came from the *Perin/Williams experiments.* If biological drive may be treated as an entity in its own right, having its own independent effects, its status as the possible basis for all motivation is more believable. We will see that McClelland (1985) still sympathizes with this feature of Hull's theory. We will discuss the Perin/Williams experiments in more detail later in the chapter.

Reward as Drive Reduction It is still popular, as it long has been, to argue that all rewards (reinforcers) act as they do because they reduce a primary or a secondary drive. An organism is hungry and this need acts as a drive to energize behavior. Behavior continues, perhaps at an accelerating pace, until food is encountered and the drive is reduced. In the future, when the organism is hungry again, it is apt to repeat behaviors that reduced the drive in the past. Do not all things that act as rewards reduce drives, as Hull believed?

What of the opportunity to explore, which acts as a powerful reward? When a rat presses a lever for the opportunity to explore a maze (see Montgomery, 1953), it may seem a clear case of reward in the form of an increase in stimulation, rather than as a decrease in a drive, unless one proposes an absurd curiosity drive, in which case the whole meaning of drive is lost.

Yet, is it not possible that curiosity, manipulation, and exploration constitute a case of a secondary drive? All that the infant rat or child need do is find that when it examines new objects and explores new surroundings it finds food, water, or another primary reward! Very early in life such behavior may thus become rewarding in itself, through its pairing with real rewards.

Secondary Drive/Reinforcement This whole account of motivation assumes that new objects and activities can evoke secondary drives and act as secondary rewards through past association with primary rewards. Is this not true? Money gains its value through the things that it buys. Solomon, Kamin, and Wynne's account of jumping dogs (described in Chapter 9) shows that a few pairings of a buzzer and shock can render the buzzer a secondary drive producer of great strength and durability. The avoiding or escaping of the buzzer acts as a *secondary* (or acquired) *reinforcer*. In other cases money acts as a secondary reinforcer and its lack acts as a secondary drive.

Drive and Learning Rate It is commonly believed that a motivated child learns more rapidly. Hull long believed that drive acts to speed learning.

Drive and Spontaneous Activity If biological drive is the basis for all motivation, one of its chief functions is its general energizing of behavior; when a strong drive is present, we are driven to action. The general energizing effect of drive may be observed by placing a rat in a closed box mounted on a stabilimeter, which monitors its movements in the box. As the time since the last feeding increases and the rat becomes more and more hungry, its general activity increases. This is the general energizing effect of the hunger drive (e.g., Munn, 1950).

Other Major Postulates

Postulate V: Stimulus Generalization Once we learn to seek food under one oak tree, we may also seek it under other trees. The cries we make when one of our parents comes near may occur as well to other adults. The specific reactions that Hull represented as the formation of a habit ($_SH_R$) generalize to other stimuli; generalized habit strength was represented by $_S\underline{H}_R$. Stimulus *generalization* occurred both with habits and with tendencies not to respond—that is, negative habits. The interaction of gradients of generalized habits to respond and to not respond was the basis for Hull's explanation of discrimination learning. But this explanation was the work of his longtime student and collaborator, Kenneth Spence, and we will leave the discussion of this theory, which is still very influential, until later.

Postulate VI: The Drive Stimulus Hull proposed that biological needs, in their function as instigators of action, may be viewed as stimuli, just as we treat external instigators of action as stimuli. In this way Hull translated motivational influences to S-R terms and subsequently treated motives (drives) as another part of the complex of stimuli influencing behavior from moment to moment. This interpretation is the same as Guthrie's (Chapter 5). Hull used the term *drive stimulus* to refer to those biological drives.

Postulate VII: Reaction Potential Habit strength ($_SH_R$) was postulated as a change in the organism, such that certain reactions were attached to certain stimuli, depending upon the number of times the S-R pairing occurred with reinforcement. But $_SH_R$ strength did not necessarily mean that the presentation of the stimulus would lead to the occurrence of the response. Habits translated to action only when the organism was motivated, which meant that some significant level of drive must be present. Drive was present when the organism was hungry, thirsty, fearful, or in some other way manifesting a need.

We all know what it means to do poorly on an exam when we know the material but cannot get motivated. A football team may have players who have all of the requisite skills (habits) to win, but it may lose because of the players' lack of desire (or motivation). Whether such statements are accurate renditions of the way things are is questionable, but Hull was certain that there is a fundamental difference between learning (habit) and motivation (drive). The more we know and the more motivated we are, the better we do; the greater the habit strength and the more drive, the more vigorous is performance. From the simple lever pressing of the rat to the most complex behavior of humans, performance is the product of habit strength ($_SH_R$) and motivation. Performance was termed *excitatory reaction potential* ($_SE_R$) and Hull believed that it was literally the product of habit strength and motivation (D). That is, $_SE_R = {_SH_R} \times D$! And he had some pretty good evidence that this was the case.

The evidence came from an experiment by Perin (1942), who basically replicated earlier work by Williams (1938). This demonstration is often referred to as the Perin/Williams experiments, and it seems to show clearly that performance is the product (as in multiplication) of learning and motivation.

In these experiments, rats were deprived of food for 23 hours and then trained to press a lever for food. Different groups of rats were trained for different durations of time and thus given different numbers of reinforcers (food pellets). Some rats were given as few as five pellets, while others received as many as 90. In Hull's view, this meant that the degree of learning, in terms of $_SH_R$ strength, differed for the different groups of rats. The rats were later deprived of food for varying lengths of time, from three to 22 hours, in order to establish different levels of drive (motivation).

All of the rats were then tested by placing them one at a time in a box with a lever and seeing how many times they pressed the lever. This estimate of response tendency is known as *resistance to extinction;* pressing the lever produces no food, and eventually the rat will stop pressing. But the more prior training it has had and the hungrier it is, the more the rat will press before stopping. The rats bore out the truth of this and did even more.

Hull's analysis of the Perin/Williams data showed that both the degree of drive (in terms of hours of food deprivation) and habit strength (in terms of number of pellets previously received for pressing) influenced the number of presses the rats made when no food was produced. The longer they had been without food, the more presses they made; the relationship was approximately linear. Plotting the number of presses as a function of food deprivation yielded a straight line (linear) increasing function. Actually, it was slightly concave upward—showing a positive acceleration—as illustrated in Figure 6.3.

The more pellets the rats received previously, the more they pressed the lever. But the relationship was not linear; rather, it was a negatively accelerated increasing function, leveling off for the groups receiving very large numbers of pellets. This is as Hull would predict, you might recall. He believed that as habit strength increases, the rate of increase becomes less, according to the equation $\Delta {_SH_R} = F(M - {_SH_R})$. Hull's rats performed as they ought.

Most impressive was the joint effect of prior training and the amount of food deprivation. When one examines the performance of the 23-hour food deprivation group that had also received 70 prior pellets and compares it with the 23-hour food deprivation group that had received only 30 prior pellets, one finds that the latter group responded approximately 30 percent fewer times in extinction. Similarly, the 70-pellet group that was then food deprived for only three hours responded only one third as many times in extinction as did the 70-pellet group that was food deprived for 22 hours. The number of presses depended jointly on the number of prior pellets given and the number of hours of recent food deprivation.

Learning and motivation are therefore different because their effects appear as different functions (linear versus negatively accelerated) and because they seem to have a combined effect on

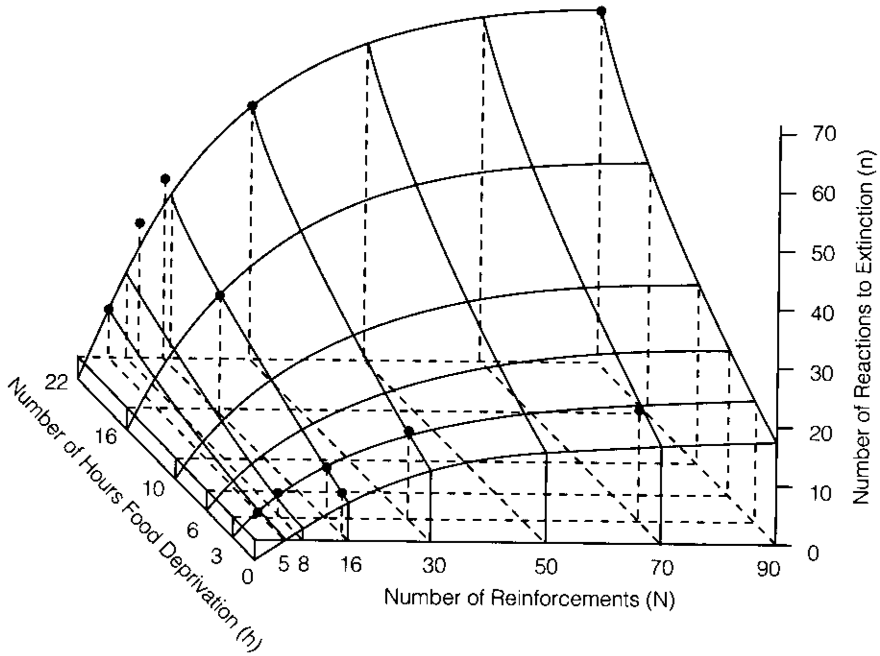


FIGURE 6.3 Hull's analysis of the Perin/Williams experiments. Points on the surface represent the joint effects of hours of food deprivation and number of reinforcements on rats' lever pressing. (Hull, 1943, p. 229)

behavior. But their effects do not simply sum; they actually multiply, claimed Hull. Using special equations beyond the scope of this book, Hull claimed to demonstrate that habit strength and motivation multiply to determine performance ($_SE_R$). It should give one pause to consider what units such a product would come in. If we multiply $_SH_R$ times drive in this experiment, we wind up with $_SE_R$ in "number of prior pellets-hours of food deprivation" units. McClelland (1985) believes that Hull was fundamentally correct, as we will see.

Postulate VIII: Reactive Inhibition Performance is not determined solely by learning and motivation; there is also inhibition, which accumulates as we move our muscles. Note the way it feels to do 50 push-ups quickly, particularly as you do the last ten. The same effect occurs after addressing 100 envelopes or memorizing a long poem. What we feel is the *reactive inhibition*—an ever-increasing aversive drive—building up and subtracting from our performance. In fact, reactive inhibition (I_R) does literally subtract from our performance.

As we rest and the muscles stop working, or as we pause in our envelope addressing, I_R ceases to accumulate and that which has accumulated dissipates with time. Hull believed that this accounted for the phenomenon of reminiscence in many learning situations. *Reminiscence* refers to improvement in performance, such as in recalling a list of words, after a period of no practice (rest). During this time the reactive inhibition that has accumulated can fade, thereby increasing the available $_SE_R$.

Postulate IX: Conditioned Inhibition Hull believed that all cases of reinforcement depend upon drive reduction; all reinforcers, such as food, reduce drives, such as hunger. He cleverly argued that this is the way we learn negative habits, or learned tendencies not to do something.

Suppose that we are addressing our envelopes or that the rat is pressing its lever or that the child is memorizing its alphabet letters. The activity continues and, whether it is occasionally reinforced with food, praise, or something else, reactive inhibition keeps building up. Whenever we act, reinforced or not, I_R accumulates. Reactive inhibition is unpleasant, aversive. It hurts to do more push-ups or to address more envelopes; it is a drag to press the bar, and it becomes annoying to continue the alphabet memorizing. Activity becomes unpleasant because I_R acts as an aversive drive, just as hunger does!

What do we do? We stop the push-ups, the envelope addressing, the lever pressing, and the memorizing and it feels good. We have stopped the buildup of I_R and that which has accumulated rapidly begins to dissipate. The aversive drive is reduced, and whenever a drive is reduced, reinforcement occurs. Thus, stopping in that situation has been reinforced, and the next time we are in that situation (doing push-ups, memorizing the alphabet, and so on) there will be a much greater tendency to stop doing it. We refer to this tendency as *conditioned inhibition*. It is represented as ${}_SI_R$.

The Remaining Postulates Postulates I through IX are really the heart of Hull's system. Along with a number of corollaries, they served as the guide for the research of countless investigators and as the target for attacks by countless others. The remaining postulates include behavioral oscillation (postulate X), which places limits on the exact prediction of behavior. This oscillation refers to moment-by-moment changes in ${}_SE_R$ because of all of the inherent variability in living things. All of the variables in the preceding postulates (${}_SH_R$, D, ${}_SI_R$) vary from moment to moment, and, since all contribute to determine the performance at a given time, performance varies somewhat from moment to moment. Hull treated behavioral oscillation (${}_SO_R$) as a form of inhibition, which subtracts from ${}_SE_R$ as do the other two forms of inhibition.

The eleventh postulate proposes a threshold that must be reached before action occurs. Remember that Hull was thinking in utterly mechanical terms; he felt that he was showing how we, as mechanisms, work and how our behavior can be reduced to the effects of learning (reinforced practice, ${}_SH_R$) times motivation (drive, D), minus inhibitory factors (I_R, ${}_SI_R$, and ${}_SO_R$). But we do not always act, at least in ways that are visible. This is because the resultant of the factors that lead to action or prevent it must be above some minimal value, the threshold, or ${}_SL_R$. The *L* comes from *limen*, the Latin word for "threshold," commonly used in the study of sensation to denote the minimal value of stimulation that is detectable.

Postulates XII through XVI deal with measures of ${}_SE_R$ and with competition among behaviors. Hull proposed that ${}_SE_R$ will be evidenced to the extent that it exceeds ${}_SL_R$ (postulate XII) and that it may be assessed in terms of latency or response (${}_St_R$), resistance to extinction, and its amplitude (postulates XIII, XIV, and XV). The last of these specifically refers to responses mediated by the autonomic nervous system. The final postulate (XVI) says that when competing response tendencies exist, the one with the higher momentary ${}_SE_R$ will prevail.

The Significance of Hull's Postulates

Hull meant his postulate system as a starting point; it included much of what was believed be true about the way we work, and it was taken for granted that it would be modified or completely changed as new knowledge was gained. After all, we must begin somewhere, and is it not better to begin with a set of clearly presented statements, rather than a hodgepodge of conflicting and fuzzily put "truths"? Hull wanted to give us a beginning and to do something to end the constant infighting among combatants who had little understanding of what the opponent was saying.

Hull also recognized that there was a lot that was not included in the postulates; for example, there is no explicit mention of anticipation, purpose, cognition, knowledge, emotion, and other things that certainly are part of what all of us think of as psychology. But in fairness to Hull, it must be understood that he planned to include all of these things, and he might have had his life not been cut short. He firmly believed that we must start with simple biological truths (or near truths) and build from there. If we begin with the simple we can progress to the complex, but not vice versa, simply because we will never really understand the complex if that is where we begin.

Hull (1952b) examined experimental evidence confirming and failing to confirm 121 of his set of 178 theoretical propositions (corollaries and theorems related to his postulates). He concluded that 106 were found to be valid, 14 were probably invalid, and only one was definitely invalid.

Hull's Intervening Variables

More than a decade before Hull wrote *Principles of Behavior*, Edward Tolman, Hull's most vocal critic, proposed that we use intervening variables in psychology. Hull agreed fully with Tolman and, when his system was unveiled in 1943, it was composed almost wholly of intervening variables. What is an *intervening variable*? It is really easy to understand, but that question has given more than one graduate student trouble. Let us begin with a list of simple things that make us do simple things and see where an intervening variable might come in handy. Before we begin, remember that Hull was avowedly a behaviorist, as were Watson and Guthrie. Also remember that Watson's main aim was to make psychology practical by concentrating on what we do (including thinking) and what makes us do it. Both what we do and what makes us do it must be identified easily; Watson wanted no fictional things inside us to explain what we do. Behaviorism speaks only of the world and our activity.

But consider this: Suppose that we simultaneously:

drink no fluids for two days

lock ourselves in a sauna

tie off our salivary ducts

eat a box of saltines

read *Lawrence of Arabia*

These are *independent variables;* they are things that we can do to produce some change in our behavior or experience. After the application of such measures for a time, we examine our behavior or experience and find that we:

think of drinking water a lot

are willing to commit crimes for water

would drink water pumped out of a river

would overcome obstacles to get water

These are *dependent variables;* they are indicants of the effects of the independent variables. Water deprivation and other variables lead us to do things to get water, and we are not as particular as we might be otherwise concerning what we have to do to get the water and the quality of the water we get.

Watson's "pure" behaviorism insisted that we explain the effects of these independent variables specifically, to avoid the traps of the old mentalism that he was trying to avoid. We would have to describe this experiment as it happened: When I drink no fluids for two days, lock myself in a sauna, tie off my salivary ducts, eat a box of saltines, and read about deserts, I will think of drinking water a lot, commit crimes for water, consider drinking polluted water, and overcome obstacles to get water! That seems a bit much when we all know that there is a common and familiar factor involved: All of the independent variables listed result in my being *thirsty*. When I am thirsty I will do all of the things listed as dependent variables. Thirst is thus an intervening variable.

It must seem amazing that anyone would object to the use of intervening variables. We drink because we are thirsty, eat because we are hungry, work because we are industrious, study because we are studious, sleep because we are tired, fight when we are angry, weep when we are unhappy, and so on. Everyone knows that this is true, and it is boring and/or insulting to be told by some psychologist that we do such things or that we do not do such things. Intervening variables are the things that we use to tie together lots of causes (in this case, heat, salt, water deprivation) and effects (drinking, thinking about drinking) and they are part and parcel of daily life. As Hull (1943) noted, the electron is an intervening variable!

We will discuss the reasons for the fuss about intervening variables in Chapter 8. Skinner did use some intervening variables in his early theorizing, but later cast them out. In so doing, he seemed to be excluding a lot of what we feel is part of life, but his reasons were compelling and we will consider them in detail.

In Hull's system, the intervening variables were too numerous for us to consider in their entirety; the major ones we have already discussed and a few more are easy to understand:

Independent Variables	*Intervening Variables*		*Dependent Variables*
reinforced trials	$_SH_R$		
deprivation of food, water, and so on	D		resistance to extinction
work done	I_R	$_SE_R$	pause before responding
stopping work	$_SI_R$		frequency of response
amount and quality of reinforcer	K		amplitude of response
similarity of stimuli	$_SH_R$		

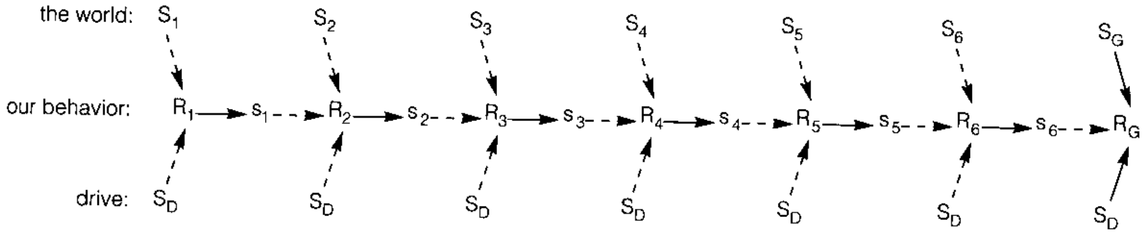
Knowledge, Purpose, and Foresight as Habit Mechanisms

In 1930 and 1931, Hull published two important papers that showed the way in which a machine might show evidence for knowledge, purpose, and foresight. The principles he invoked were well-accepted ideas in the psychology of the nineteenth century and it is interesting to see the way in which he used them. This achievement was, in a way, the capstone of the associationist philosophies; it extended their basic views to areas where only philosophers had tentatively ventured and made the associationist-mechanist view seem a natural extension of the known principles of biological functioning. Here is the story.

What sort of behavior and experience would seem to be most difficult for someone like Hull to explain in mechanical terms? How could anyone build a machine (his basic approach) that would show evidence of knowledge, purpose, and foresight? Further, how could this be done in such a way as to roughly follow accepted biological principles? Let us consider two examples, one dull but traditional and another less dull and less traditional. In the first case, consider a rat that is running an alley and receiving food at the end. In the second case, consider yourself on your way to accept an award, to be received in a familiar place. How would Hull account for the behavior shown and for the experience that we (and the rat) have?

Knowledge Hull believed in starting with the most basic determinants of behavior and experience; in so doing he made a number of simplifying assumptions, especially in cases such as the ones we are considering. The first assumption was that the world affecting us may be simply represented. What is the world affecting us? Poets and writers, not to mention philosophers, have anguished over this problem, but for practical purposes, Hull suggested that it be represented as follows:

the world: $S_1\ S_2\ S_3\ S_4\ S_5\ S_6\ S_G$



This is surely simple enough; the *S*s stand for stimuli and the sequence from S_1 on represents a "world sequence" of stimuli passing along. The sequence in this case ends with S_G, or a *goal stimulus*. This amounts to food, receiving the award, or some other situation that reduces a biological drive or a secondary drive.

We experience this sequence of stimuli (the "world") either because it is passing as we watch or because we are moving through it. The former case could refer to the watching of a movie or listening to a song, but the latter case is of concern here. We are moving along, and as we move we encounter S_1, S_2, and so on to S_G. The movements of the muscles (including the eyes) provide more stimuli, assuming we are talking about a high-grade organism with proprioceptors. Muscle spindles and Golgi tendon organs let us know the position of our limbs, and they do so by reacting when we move a muscle or a limb. Thus, the feedback from movement becomes an additional source of stimulation, so that our first journey through the sequence of stimuli results in the situation represented above.

The series of *R*s represents our behavior as we progress through the stimulus sequence (that is, the "world series"). Following each R is a lowercase *s* with the same subscript as the preceding R; these are the proprioceptive feedback stimuli produced by each response we make. Each response is different, so each *s* is different. This introduces something interesting and by no means original with Hull. This gives us a basis for knowledge in this organism. Consider what we have so far.

The world sequence is either the sights and smells of the alley, if we consider a rat running an alley, or the things we see and hear as we are on our way to the award ceremony. The behavior sequence represents movements along the path, and these occur in the presence of the corresponding stimuli; R_1 goes with S_1, R_2 goes with S_2, and so on. Recall that Hull's fourth postulate said that stimuli accompanying responses that were followed by drive reduction become attached to those responses; as long as this series of stimuli and behavior ends with a drive-reducing S_G (food for the rat and the secondary-drive-reducing award for us), those stimuli will become connected with those responses. The next time we or the rat are in the presence of S_1, R_1 will be likely to occur and the succeeding stimuli in the series will be apt to produce the behaviors that last occurred in their presence. Needless to say, the behaviors closest in time to drive reduction, such as R_5 and R_6, will be more closely connected to their stimuli. But unless the delay between S_1 and R_1 is too long, the more remote connections will also be made. The broken lines represent new connections between these stimuli and their responses.

In addition, we also have the proprioceptive consequences of each of these responses and, of course, each of these are different and mirror the responses that produced them. Thus, we have the "world series" of stimuli, each connected to specific responses. Each of these responses produces feedback that we can feel, although we do not ordinarily pay much attention to such feedback. In a real sense, the feedback *s*'s are a copy of the world sequence of stimuli. The sequence of feedback stimuli is within the body and thus acts as a copy of the world sequence of stimuli.

This was Hull's proposed mechanism for the acquiring of knowledge. Is it reasonable?

It certainly is, and put in less gross (S-R) terms, it has a long and distinguished history, especially in American pragmatic philosophy and in functionalist psychology, although Hull cited no sources there. Let us consider a common example. Suppose that you are entering some great hall, such as a huge room in the Versailles palace or a large alien spaceship. Or suppose that you are simply exploring your new home. In all such situations, you may simply stand at the door and see everything within about as well as it can be seen in order for you to get a good impression of what is there. But in all cases, it seems necessary to walk slowly through whatever space is involved and you may walk through it repeatedly. You are getting to know the place, to have knowledge of it which you can carry away with you. And this knowledge comes from what you see, from the effort it almost unconsciously takes to focus on the high ceilings and from the way it feels to walk through it.

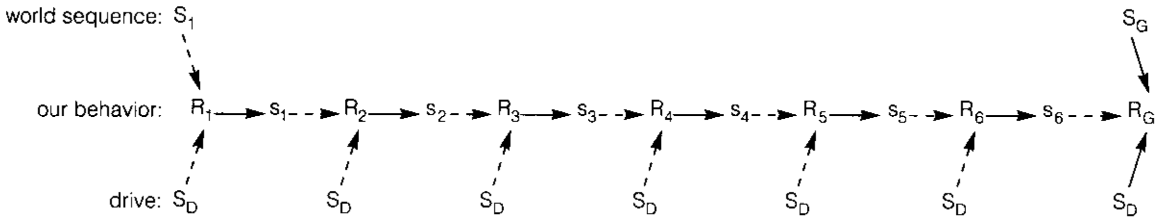
Visit someone who lives in a very old fashioned house with a very large living room and very high ceilings. In a 30 ft × 60 ft. living room, one has an irresistible urge to walk around through it to *know* just how big it is! This moving through our surroundings and the way it feels to do so is a large part of the way that we come to know the world. You know that a written description or a picture is no substitute for direct experience. And direct experience must include action on our part. If you want to know what a hammer is as well as I do, hit your thumbs and fingers routinely with a hammer. In large part the world and its objects are our reactions to it and them.

Foresight So the rat running down the alley and our trip to the award ceremony leave connections between the stimuli that pass by and a copy of the trip in the form of movement-produced stimuli. But wait! The movement-produced stimuli *are* stimuli, and therefore they obey Hull's fourth postulate. They are present when a response is made that is followed by drive reduction, and they therefore become connected with the appropriate responses. Thus, s_1 becomes connected with R_2 and s_2 becomes connected with R_3, and so on. This adds quite a bit to the situation.

All that Hull's machine (the rat or us) now needs to get it or us going and continuing to go is S_1. That leads to the first response, R_1, which produces its proprioceptive feedback, s_1, which is connected to R_2; thus, it can produce R_2 even in the absence of S_2. We no longer need the world sequence, because once we have started action, the proprioceptive stimuli can produce the next response, which leads to more proprioceptive stimuli and the next response, and so on. This is a *chain* of behavior. If the initial stimulus is present, the first act leads to the second, and so on, with the intermediation of the response-produced stimulation that goes with each response.

Such chains are common in human life. We go through a sequence of movements in buttoning our blouses, shirts, or sweaters, which is begun and rattled off with no thought on our part. Do you begin buttoning a blouse or shirt at the top or at the bottom? There go your hands, miming the act, right? In such common activities, we rely almost entirely on proprioceptive/kinesthetic stimuli that come from our tendon organs and from our muscle spindles and that lead to the next act. Your fingers know how to strum a guitar or sew a button and your arms "know" how to hit a punching bag or a baseball. If you try to attend to the details of such actions, you will make errors.

What happens then when the rat reaches its goal box and we receive the award? The S_G, or goal stimulus, is a drive-reducing event and produces an R_G, or goal response. The eating of the food reduces the rat's hunger and the receiving of the award reduces secondary drives. Through the whole sequence, the rat is hungry and we have yearnings for the award, which motivate the rat and us as we go through the sequence. Hull viewed all of motivation in terms of drive stimuli, which are like any other stimuli and which become connected to the behaviors that occur as we



go through the sequence. When we are later in the same drive state (hungry or yearning), we will be more apt to go through the same behaviors that lead to the goal object on this occasion.

Let us now consider foresight. Suppose that the rat is later tracing its familiar route to the food or that we are tracing our familiar route to our award. All of the stimuli of the world sequence are connected to our past behaviors on that route, as are the proprioceptive stimuli (the lowercase *s*'s) that form the chain. And all of these behaviors are also joined to the drive state involved in the past (that is, the S_D). This means that we can carry out the sequence of behaviors leading to the goal stimulus without the specific stimuli of the world sequence. All that is necessary is that the sequence be set off and that it can continue by itself. It happens as shown above.

What has happened is that the stimulus of the world sequence that begins the sequence of behaviors has caused R_1 and that has produced s_1, which produces R_2, which produces s_2, and the rest of the chain (R_3–s_3–R_4 . . .) runs off by itself; we do not need most of the world series. The rat enters the alley and is affected by the sight of the start box and the beginning of the maze; we set out to receive the award and are on our way. In such well-practiced sequences of behavior (or experience) in which the initiating stimuli have had their effect, the rest of the chain goes off automatically, as is common in daily life.

This is a very reasonable explanation for much of what we do. The first time we ride a bicycle, it is necessary to attend to each stimulus coming from our muscles, our organs of balance in the inner ear, and the sight of the ground beneath us. But after we have gone through such painstaking initial efforts, bicycle riding (or dancing, or driving an automobile) has only to begin, and our past habits carry out all of the specific movements for us. In addition, this chaining of movements and proprioceptive stimuli also accounts for instances of foresight.

Suppose that the sequence we are considering is one that ends with a goal stimulus (S_G) that is something we either value highly, such as high praise, or something we find very aversive, such as being mauled by a pack of wild dogs. We begin a sequence of behavior, with no particular idea in mind as to where we are going. The world sequence sets off the chain of behavior and movement-produced stimuli and we foresee the culmination of our trip. The chain runs off *faster* than the objective world sequence and we reach the S_G long before the sequence of S_1, S_2, and so on leads us to it.

Similarly, such chain-produced foresight keeps us out of the jaws of the pack of wild dogs. As we turn a corner, we recognize that this is the way to the wild dogs' home and the chain of behavior and movement-produced stimuli that have resulted from past excursions in this direction leads us to a mental S_G and allows us to rechart the course and thus avoid the danger to which that course led us in the past.

Purpose "What more do we mean by foresight?" asked Hull. A more potent form of foresight comes from the effect of past goal attainment. Behavior with respect to goals (the rat reaching its food, our reaction to the award) is the goal response (R_G). The goal response is closely related to the particular drive state we are in (the S_D), since that is what makes a goal a goal. Food, water, or activity are S_G's when our S_D (drive state) is hunger, thirst, or need for activity. When such drives are not present, such goals do not act as goals.

After a bit of experience in running through the rat-to-food or the us-to-award sequences, both we and the rat seem to act less mechanically than Hull's basic theory seems to require. The rat runs faster as it progresses down the alley and we may notice drops of saliva on its cheeks. Our path to the award is accompanied by thoughts of it and by anticipation of its presentation. How can mechanical entities, such as the rat and us (in Hull's opinion) seem to show anticipation in this way?

This was explained by Hull (1931) as the effects of the *functional antedating goal response*, sometimes called the anticipatory goal response, and represented by r_G–s_G. This is a totally mechanical addition to Hull's totally mechanical theory, and he used it to account for a variety of things that we and other animals do. Here is how it works.

Why does the rat move in the alley at all, even on the first occasion in which it is placed in it? It has not learned at that time that there is food at the end of the alley, but it is hungry and hunger acts as a drive (an S_D), which produces activity, just as Guthrie's maintaining stimuli produced action. S_D is simply another name for the same thing, although Guthrie meant to include more than biological needs when he referred to such stimuli.

Because of the way the alley is built, the rat will eventually reach the goal box and the food, just as it would probably eventually find food if it were hungry in the wilds. When the rat finds food for the first time, by accident, so to speak, it responds as one does to any goal stimulus (S_G)—with a goal response (R_G). Ingeniously, Hull pointed out that the goal response was a response similar in kind to any other response, and thus subject to postulate IV: It was a response closely preceding the reduction of a drive (obviously) and therefore would become connected to stimuli present at or near the time it occurred. This means that the response will become most strongly connected to the sight of the food, of course, since that is what was present at the time it occurred, but it also will be connected to stimuli present near the time it occurred. Thus, it will be connected to S_6, S_5, and even more remote components of the world sequence, as well as to s_6, s_5, and more remote movement-produced stimuli. With repeated trials, the connections between these stimuli and the goal response (R_G) will become stronger and stronger, and eventually even S_1 and s_1, the first component of the world sequence and the first stimulation produced by movement, will produce a strong (R_G) goal response.

Remember that Hull was trying to build an organism that would act as humans do, and the problem of accounting for anticipation and goal direction was a big problem for such an enterprise. He showed how his model could account for such behavior and, although he has been proved partly wrong in tests that took him literally at his word (see Bolles, 1978), his solution to the problem has had great influence. For example, one process, which will be described briefly below, was adopted by McClelland and his associates (McClelland, Atkinson, Clark, & Lowell, 1953), who used it to justify their method for testing the achievement motive (nAch), and as the basis for a general theory of human motivation, a topic to which we will return.

Getting back to the rat, we now have the goal response (R_G) connected to the stimuli of the world sequence and the movement-produced stimuli that link together the chain of behavior that guides the rat to the food (and us to our award, in exactly the same way, as the reader can imagine). Plus, the goal response is not really *any* response, because the organism involved is in a state of need of one kind or another (for example, the rat needs food), so that the drive state that is current tends to produce the goal response.

Thus, experience going through the sequence and the nature of S_D both lead to the possibility of R_G occurring as soon as the world sequence begins. (Hull (1931) said that this explained premature ejaculation.) The general principle, if true, means that we and the rat would begin showing goal responses as soon as any familiar sequence of behavior begins. And this is not far from the truth.

Suppose the rat begins to think of food, salivate, chew, and make food-grasping movements with its paws as soon as it is placed in the alley. If it continues to do this, what happens? If it stays where it is, or somehow manages to run on two feet while doing this "sham eating," it either never gets to the goal box and the food or it gets there very slowly. This means that when the rat makes the whole goal response when not at the goal, the food and the drive reduction are delayed somewhat or the drive reduction does not occur at all.

Behaviors that require effort but do not lead to drive reduction simply cause a buildup in reactive inhibition (I_R) and no buildup in habit strength (${}_SH_R$); thus, the behaviors extinguish (drop out). Thus, the goal response prevents the delivery of food unless it is done when food is present and so it extinguishes at other times. But Hull pointed out that the goal response is a complex set of activities and that not all of them impede the progress of the rat or of us to the goal.

For example, the rat's goal response to food includes its seeing the food, smelling the food, chewing the food, picking up the food, swallowing, and so on. Only the picking up of the food, if done before the rat reaches the food, impedes progress toward the goal. The rat can see (imagine) the food, smell it, chew, salivate, and do other things it does while it eats, and still run. These components of the goal response (R_G), which can go on without slowing or halting the rat's progress toward the goal, are little r_G's, fractional antedating goal responses, and they grow stronger with successive trials.

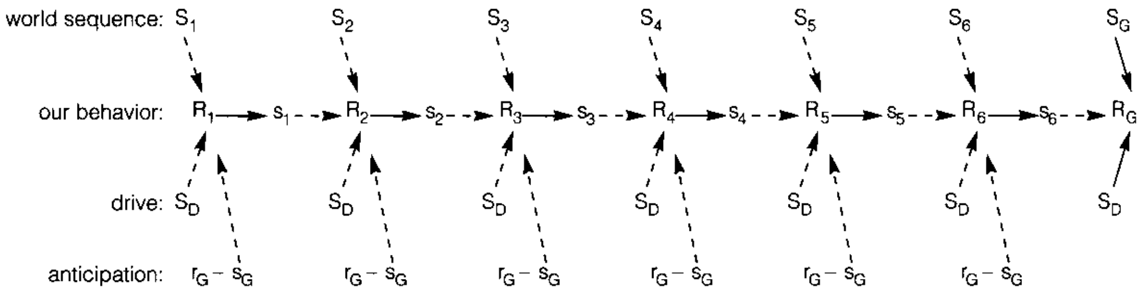
Those components of the goal response that interfere with the progress toward the goal and drive reduction drop out, since they are not closely followed by drive reduction. These components include things like stopping to seize and eat imaginary food. But the components of R_G that do not interfere have a motivational effect.

The effects of an ever stronger r_G appear in the rat's behavior as visible food-related behavior while running the alley. The rat may salivate, make chewing movements, and do other things that we can see and that suggest to us that the rat is on the way to food, and the rat may be imagining the taste and sight and smell of the food, for all we know. We have all experienced going through sequences that had a predictable ending enough to see the truth of this; how do we act on the way to see a loved one, learn an exam grade, receive a beating, eat breakfast, and a host of other familiar sequences? We "anticipate" the end result of our behavior. We see, hear, and in other ways do what we have done to reach that goal before. We wince or exalt as we have done before when receiving an exam grade, even though the moment of reckoning is yet to come. In a real sense, when we do these things, we are doing what we have done in the past in the presence of goal objects, but the goal object is not yet present and so we do the best we can.

Ralph Barton Perry, biographer of William James, addressed the same matter in a 1918 paper. When a dog is chasing a rabbit, Perry explained, it is actually "eating" the rabbit during the chase. It is making a variety of antedating goal responses, and only the physical grasping of the rabbit is needed to consummate the act.

Besides the anticipatory reactions that occur when we progress toward familiar goals, we also speed our movements toward such goals, the closer we come to them. The rat accelerates as it nears the goal and we speed up as we turn the last corner on the way to receive the award. This cannot simply be due to the fact that our fractional anticipatory goal response is stronger near the goal. Since such responses are closest to the goal and to drive reduction, they *are* stronger, but why should the rat's stronger salivation (and so on) lead it to run more rapidly as it approaches the goal? This does occur, though, because of the stimulus consequences of the anticipatory response.

Just as the movements we make produce sensory consequences (as when R_1 produces s_1), frac-



tional antedating goal responses produce stimuli, which Hull called s_G. Little s_G is the way it feels to salivate and to prepare in other ways to eat food, and it is the way it feels when we anticipate the receiving of our award. We have already seen how postulate IV specifies that r_G occur in advance of the meeting with the goal object, so there is no difficulty in accounting for why s_G occurs early in the sequence; it is produced by r_G.

However, s_G is a stimulus and it also obeys postulate IV; all stimuli present when responses occur shortly before drive reduction become attached to those responses. So s_G becomes an added determinant of the responses in the sequence, along with the stimuli of the world sequence and the stimuli produced by movement toward the goal object. Little s_G is more strongly attached to those responses that are closest to drive reduction, and this accounts for the acceleration as we approach our goal and the rat's acceleration as it nears its food.

This, then, is Hull's (1930, 1931) explanation for our behavior when we go through a sequence of stimuli that we have gone through often in the past. Knowledge is accounted for as the product of action-produced stimuli, which leave a copy of the world sequence within us, translated into our reactions to that sequence.

To complete Hull's account for knowledge, foresight, and purpose, we have only to add r_G–s_G to the mechanisms described so far. Recall that s_G, being a stimulus, obeys postulate IV and becomes an added evoker of each response, especially those nearest the goal stimulus. This is the basis for anticipation and the acceleration shown as a goal is approached. The final diagram is above.

Practical Application of Hull's Theory

Hull spent a lot of time applying his theory in animal research, and most of his amazing predictions of experimental results refer to animal research. He was a master at attaching numbers to the habit strengths assumed to be present in a given situation and then going through a complex set of deductions, using equations described in his major works (1943, 1952b) and arriving at results so near those actually obtained that critics blanched. (The reader may wish to consult Hull's 1952 book to see just how good he was at predicting the minutest details of an experimental result.)

But Hull's overall goal was to explain that which is worth explaining; it is clear in his writings that he felt we must first make a convincing case for the possibility of explaining complex behavior. If his death had not cut short his work, he may have gone much further than we might guess in dealing with complicated behavior. His students' work suggests the directions he would have taken, and the transcripts of his "Monday-night group" at Yale outlines the sorts of analyses he planned for a range of complex psychological phenomena.

Hull had no formal duties at Yale from 1929 until his death in 1952, aside from the directing of a mass of research carried out by some of the most capable workers in psychology and biology in the country. He met with collaborators and students on Monday evenings, and the results of the presentations made by Hull and others were recorded. The following applications and interpretations come from a copy of the *Abstract of S-R Sessions of Monday-Night Group*, 1938–1939, of the Institute of Human Relations, Yale University, which was obtained from W. S. Verplanck, a former acquaintance of Hull. The presentations include pieces by Neal Miller, Hull, O. H. Mowrer, Carl Hovland, P. H. French, G. P. Murdock, J.W.M. Whiting, and D. G. Marquis. Hull gave the following homely examples during these sessions to illustrate the strong effects of reinforcement in daily life:

> The principle of reinforcement is operating constantly and we have all been familiar with it since childhood; the only thing strange about it is the name. The meaning of the term will become clear with a few simple examples. . . .
>
> If a nation in need demands a satisfaction of this need from another nation on threat of war, and if the second nation yields, the demanding and threatening by the first nation will be *reinforced* and it will be more likely to repeat the behavior subsequently when a similar situation arises. . . .
>
> If a racketeer attempts any sort of blackmail and the victim yields, the blackmailing behavior will be *reinforced* and therefore strengthened. But if all prospective victims should uniformly refuse to yield, this [blackmailing] behavior will suffer extinction. . . .
>
> If an infant says "da-da" and he is praised and approved, this behavior will thereby be *reinforced* and the child will say it more readily on subsequent similar occasions. . . .
>
> You are painfully ill and you do various things to relieve your illness. Finally you take a certain medicine, whereupon you at once grow better, thus reinforcing the tendency to take that medicine the next time that you are similarly ill. . . .
>
> A child by trial-and-error joins a certain word sequence and escapes punishment—thus *lying* is reinforced.
>
> A person by trial-and-error joins certain words together and his anxieties disappear. Thus *rationalization* is reinforced. . . .
>
> A child speaks certain words to *himself* while in a problem situation and these words evoke a reaction on his part which solves the problem. Thus *reasoning* is reinforced. . . .
>
> Later, special rules are tried out and by trial-and-error those rules which mediate problem solutions successfully are reinforced and the others are extinguished. Those words which survive this trial-and-error procedure become *logic*. . . .
>
> A person with much anxiety, if relieved by psychoanalysis, will have the tendency to go to the analyst and to cooperate with him, reinforced. He will also pay the analyst, reinforcing the analyst's behavior, and thus creating a *reciprocal habit complex*. This circle is said to be broken after a time by a failure of the anxiety to recur. At that time the patient would terminate the analysis. . . .
>
> A person receives a shock in an accident and receives insurance for injury, thus removing the necessity of working, and so reinforces the symptom. Such cases are said to be hard to cure.

Such examples are sufficient to give an idea of the way in which Hull's analysis could apply to international conflicts, blackmail, the learning of words, lying, rationalization, reasoning, logic, the tendency to continue psychoanalysis or other treatment, and injuries that seem to take an overly long time to heal. His analysis actually is no more than an application of the general principle of reinforcement to common behaviors. Thus, it is by no means original with Hull. It is included to show that he was concerned with such problems and that he was confident that S-R associationism and the law of effect was enough to deal with them.

3. CRITICISMS OF HULL

The Stress on Molecular Interpretations

We will see that Tolman (1932) had emphasized the importance of the distinction between molecular and molar treatments of behavior. We will go into the details of this distinction later. Suffice it to say that Hull was a molecular theorist, despite his frequent assertions in 1943 that his was a molar theory.

What was (and is) meant by the molecular/molar distinction is the problem of what constitutes behavior and experience. Suppose I walk to the store to buy milk. How can I describe this act if I am interested in explaining all of what I do? I called the act "walking to the store," but this molar way of describing things may not be appropriate. Such a description defines activity with reference to goals, and Guthrie made a good case for not doing such things. If we see someone walking and it appears to us that she is heading toward a store where milk can be bought, we may guess that this is the goal of the walker. But this may not be the case, and such descriptions are not useful if one wants to do a scientific analysis of behavior. Thus, Hull (despite his denial) was an advocate of molecular analyses of behavior. (Neither he nor Tolman were very interested in experience, but the same point of view would prevail there, whether dealing with behavior or experience.)

Hull was the ultimate molecularist, and this meant that for him any explanation of behavior had to be cast in what Tolman called the ultimate causes of behavior. The walk to the store to buy milk appears so only because we overlook or ignore the real state of affairs. This consists of muscular movements and secretions of glands; although Hull felt himself to be molar because he was not dealing with the contractions of individual muscle fibers, he was in fact concerned with the movement of groups of muscles and the movement of limbs. Although Watson and Guthrie both advocated such a position, they usually dealt with quite large chunks of behavior and they dealt with experience. Hull stayed with the ultimate determinants in theory and in practice.

This is embodied in his emphasis on the importance of being able to test theories by building a machine that functions as the theory predicts. In fact, we are muscles and bone and blood and nerves and glands. And if we are to understand ourselves, we must understand the workings of our bodies.

Hull's mistake, according to critics, was his insistence not only on biological determinants of behavior, but on a molecular view of the workings of the body. Hull was by no means an authority on biological matters, and he accepted the common view that we are a collection of parts and that our behavior is merely the sum of those parts; this was exactly the point of view that James Mill had taken in his account of mental phenomena. In his view, there are numerous separate pieces that, when added up, comprise mental life. For Hull, there are separate muscle movements and secretions of glands, and when you add them up you have behavior.

The general point of view is difficult to criticize. When you hear someone say that an apparent trip to the store to buy milk is really a sequence of muscle movements and glandular secretions, you secretly chuckle. But someone may show you a vial of brown liquid and, after you see, smell, and taste it, you are told that it is really a solution of beef molecules in water. It seemed to be just beef broth. When we get down to it, the world and our behavior and experience are really whatever are the smallest elements into which we can analyze. Isn't everything really made of atoms?

Hull's view was shaped by the status of the sciences in the 1920s and 1930s, which led to his emphasis on molecular analysis. All of the criticisms that the Gestaltists heaped on Titchener count as heavily as criticisms of Hull. We will see in the next chapter that Tolman, who sympathized with the Gestaltists, tried very hard to combat Hull's extension of Titchener's molecularism.

The Hypothetico-Deductive Approach

As mentioned earlier in the chapter, Hull's fascination with the hypothetico-deductive method arose after his reading of a paper by Einstein, which was published in the 1930s. (Kenneth Spence related this information in his introduction to the seventh printing of Hull's *Principles of Behavior*.) Although others dispute Hull's conclusion, Hull was convinced that Einstein had used the method of formal postulates and the deducing and testing of theorems originating with the postulates.

Hull also pointed to Isaac Newton's *Principia* as a model, with its "classical scientific theoretical system of the past," which began with seven definitions (matter, motion, and so on), continued with a set of postulates (his famous three laws of motion), followed by 73 formally proved theorems and many appended corollaries (Hull, 1943, p. 7). Can Newton's method be a bad one?

Given the conditions of the time, Hull's method seemed very attractive, and it is easy to see why it converted so many to his point of view. Instead of the hodgepodge of conflicting theories and the neverending debates among psychologists and philosophers, we would begin together, with a clearly worded set of general principles; together we would make deductions from the postulates and test them. As the tests showed a theorem to be in error, we would modify it. If a number of theorems were so altered, we would change the postulate.

It was taken for granted by Hull that the postulates were no more than reasonable assumptions about the way we work; they obviously were not completely accurate, or we would now understand exactly how we operate. But if we constantly test and modify them, we will slowly but surely improve them and eventually we will have a set of true postulates. Who could argue with such a proposal? What could be wrong with a self-correcting strategy such as this one? Many did not argue and Hull's popularity was undoubtedly in great part due to the promise that this method seemed to hold.

Yet, by the early 1950s, scarcely more than a decade after Hull had unveiled his system, there were few psychologists who still believed that such a method was useful. One reason for the failure of the hypothetico-deductive method was the difficulty encountered by clearly testing theorems. If one could do an experiment that clearly and conclusively shows, for example, that all reinforcers do not involve drive reduction, then one could appropriately modify postulate IV. But there have been countless experiments done with humans and other animals since the 1940s aimed at clarifying the nature of reinforcement. We still do not understand it in the way in which Hull defined *understanding*.

Experiments never come out absolutely, clearly, and unambiguously in favor of or against a hypothesis; such a clear and unambiguous experiment, which shows to everyone's satisfaction that a hypothesis was true or false, is known as a *crucial experiment* and such things are hard to come by.

Hull was in a position to have the best research facilities and the best researchers available, in addition to having tremendous influence with the journals that publish research results. (If the results of an experiment are not published, they do not exist. This means that a research finding must bear the scrutiny of reviewers working for the journals (without pay, of course) before one can be sure that the experiment was properly conducted and therefore that the data are believable.) Opponents of Hull's basic views may have had more than their share of difficulties in getting their work published, and, once it was published, they could expect a counterattack from Hull's group. Many of his assistants and colleagues, such as Spence and Miller, were masters of research and could effectively point out the deficiencies in findings critical of Hull's views and then show experimentally how Hull's position was actually the correct one. Thus, the necessity for crucial experiments and the influential position that Hull enjoyed rendered the self-correcting system more a self-perpetuating system!

Hull's Ignoring of Private Experience

Since Watson's time, critics of behaviorism have charged that behaviorists either deny the existence of conscious experience or claim that it has no place in a scientific psychology. The first charge is absurd, of course, and comes from the insistence of Watson and others that the *terminology* of the introspectionists be abandoned. We found in Chapter 4 that Watson and other behaviorists were interested in experience but that they insisted it be treated as behavior, that is, as activity. This means that we think and imagine but that we do not think thoughts and imagine images. In this way, the early behaviorists, including Thorndike, Watson, and Guthrie, were stressing the importance of action (dynamics), as opposed to statics (images and ideas), which the introspectionists emphasized. The early behaviorists were not denying the existence of subjective experience, nor were they claiming that the study of it was outside psychology.

Hull and his colleagues, on the other hand, did argue that the study of subjective experience was outside scientific psychology. It may be that this was inevitable for Hull, who saw the future in this way:

> Progress in this new era will consist in the laborious writing, one by one, of hundreds of equations; in the experimental determination, one by one, of hundreds of the empirical constants contained in the equations; in the devising of practically usable units in which to measure the quantities expressed by the equations; in the objective definition of hundreds of symbols appearing in the equations; in the rigorous deduction, one by one, of thousands of theorems and corollaries from the primary definitions and equations; in the meticulous performance of thousands of critical quantitative experiments and field investigations designed with imagination, sagacity, and daring. . . . There will be encountered vituperative opposition from those who cannot or will not think in terms of mathematics, from those who prefer to have their scientific pictures artistically out of focus. (1943, p. 401)

If anything characterized Hull, it was objectivity, and subjective experience is not objective. It is a pity that Hull took this position, because his great influence damaged the behaviorist position greatly, to the extent that many believe that all behaviorists fundamentally agreed with Hull and therefore saw themselves building robots and ignoring private experience. Interestingly, Hull's archcritic, Edward Tolman, was in agreement with Hull on this issue, ridiculing any concern with subjective experience shown by those who were supposed to be engaged in the scientific study of behavior!

Hull's emphasis on objectivity, as embodied in his hypothetico-deductive method, was due to his concern that we be able to tell when we are mistaken. What he opposed was the hiding of a possible mistake "behind weasel words, philosophical fog, and anthropomorphic prejudice" (1943).

The Case Against Drive

Hull, like Freud and many other psychologists, believed that biological drives were the basis for all motivation. This position was especially associated with Hull, and there is no doubt that his authority and data added status to the theory. It may be that drive theory is correct by definition; if we use *drive* to refer to something that energizes our behavior, then we are using the term interchangeably with *motivation*. Motivation is in that case merely a matter of drive arousal and satiation. But drive theories usually mean more than that: A drive is a biological affair. For Freud (1915), the life instinct acted as a drive (*Trieb*) seeking gratification and the whole apparatus of the psyche was built upon this. For Hull and others, all behavior (including thought) ultimately served the basic biological drives, such as hunger and thirst. Many have opposed this view of motivation, and we will illustrate their objections by discussing criticisms of the evidence for the fundamental importance of biological drives covered earlier.

The Few Motives of Infants Just because we come into the world with few motives and have many in adulthood does not mean that current motivation in any way depends on primary motives. Let us consider this further when we discuss Allport's insightful attack on the instinct and drive positions. We will discuss this in the following subsection.

Specific Hungers Hunger for specific foods has long been considered one of the wonders of nature. But Rozin (1967) took away much of the wonder when he pointed out that specific hungers may be accounted for largely as an instance of learned taste aversion. For example, the deficiency of a nutrient makes an organism sick and it quickly prefers different food. The deficient organism is not (in most cases) seeking out nutrients to remedy the deficiency. It simply doesn't want to eat its old food, which left the organism sick! We will discuss this explanation of specific hungers further in Chapter 9.

Separation of Learning and Drive It is true that the Perin/Williams experiments showed that it was possible to separate the effects of hunger from those due to amount of previous training, so, in a sense, learning is separable from drive. But even in this case, the division is not so neat as it may seem. The statement that drive and learning are separable and that they multiply (that is, ${}_SE_R = {}_SH_R \times D$) is true only to the extent that Hull's methods of calculation are accepted; these days they are not (see Seward, 1954). And *learning*, as defined in the Perin/Williams studies, was a function of the number of reinforced lever presses preceding the test in extinction. Since food pellets are drive reducers (in Hull's sense) for hungry rats, was the lever-pressing training really free of the influence of motivational factors?

Reward as Drive Reduction Masses of data collected during the 1940s and 1950s clearly showed that a great many things that do not reduce biological drives act as strong reinforcers. For example, saccharine has no nutritive value and passes unmetabolized through the body. Although it reduces no drive, it acts as a potent reinforcer of the behavior of rats and many other mammals. Other instances, stressed by Harlow and Hebb, show that *increases* in drive may act as reinforcers. A male rat will run increasingly rapidly down a runway for the reward of mounting a female, although he is pulled off before his aims are accomplished (Sheffield, Wulff, & Backer, 1951). It is difficult to interpret such a consequence as a drive reducer!

Secondary Drive/Reinforcement The drive theory of motivation assumes that cues paired with primary (drive reducing) rewards may become rewards in their own right. We may have a secondary drive for attention because attention has been paired with the satisfaction of many primary drives in the past. If we examine surveys of the research showing this process, such as Mackintosh (1974) or Nevin (1973) or Gollub (1977), it becomes clear that the pairing of a cue with a primary reward lends that cue very temporary and fragile reinforcing power (see Chapter 9). On the other hand, cues paired with aversive events, such as electric shock, gain quite considerable power. This has led some drive theorists (e.g., Brown, 1953) to suggest that learned fear is the basis of all motivation. Harlow (1953b) countered that it is the drive theorists who need to be nervous and fearful.

Drive and Learning Rate Common sense tells us that motivation may aid learning but that learning does not improve with increases in the strength of biological drives. Would a food-deprived class of children learn more rapidly than a food-sated class? The research cited to show the beneficial effects of drive on learning involves very simple situations and very simple learned behaviors. Broadhurst (1957) and Spence (1956) are often cited as having provided evidence for the increase in learning rate when drive is increased, but their data probably do not generalize well. Broadhurst observed the effect of air deprivation on the learning of an underwater Y-maze in rats, and Spence's data involve eyelid conditioning in humans. Drive, in Spence's case, was manipulated, for example, by varying the strength of a puff of air directed at the subject's cornea. Increases in hunger, thirst, or other drives may lead to increased speed of running in an alley, but not to improved performance when the learning is even mildly more challenging (cf. Mackintosh, 1974).

Drive and Spontaneous Activity As drive increases, activity does not necessarily increase. Even the rat, left alone in its box on the stabilimeter, does not increase its activity as its hunger increases. Nor would it be adaptive for the rat to become increasingly active; why burn calories moving around, once it is clear that there is no food to be found and that escape is impossible? Campbell and Sheffield (1953) did show that such a rat will respond more and more vigorously when an experimenter comes to look into its box, but that is hardly the blind energizing effect of drive. The rat does become hungrier and hungrier, and when a member of the species that has fed it in the past comes to look in on it the animal reacts more and more vigorously as the time without food increases. If the rat is checked every half hour, with an accompanying burst of activity on its part at those times, it may appear that its general activity increases with time, especially if its activity is plotted in one- and two-hour blocks.

FIGURE 6.4 Gordon Allport, 1897–1967. Allport, a psychologist and professor at Harvard University, was a noted personality theorist. He was best known for his theory that adult motives may stem from the basic motives of the infant but soon become functionally autonomous. *Courtesy of the Archives of the History of American Psychology*

Allport's Functional Autonomy of Motives

In 1937, long before criticisms of drive theory were popular, the personality theorist Gordon Allport (see Figure 6.4) argued convincingly against such theories. He believed that both instinct theories (such as McDougall's) and drive theories (such as Hull's and Freud's) were fundamentally in error. What such theories attempt to do, he claimed, is reduce the seemingly infinite diversity of adult motives to a few instincts or biological drives. For example, if a person is motivated by the desire to keep life as simple as possible, as was Tolstoy after his religious conversion, is that person really manifesting a death wish or the instinct for submission, as Freud and McDougall respectively suggested?

Allport felt that adult motives were far too varied and unique to be reduced to a few basic instincts or drives. (Interestingly, he published a paper listing more than 17,000 trait names corresponding to the same number of motives; see Allport & Odbert, 1935.) How then do we deal with motivation? Do we just conclude that a given individual may be motivated by any of an infinite set of motives and leave it at that?

What we can do is try to understand how this uniqueness comes about. How do the many motives of adulthood gain their power? Allport suggested that they do so because of an earlier connection with the basic motives (instincts and drives) of the infant but that they subsequently become functionally autonomous.

Consider the infant, motivated by hunger, curiosity, and other basic drives. There is a shiny button on a tabletop, out of reach of a crawling child. To get the button, the infant stands (and falls, and stands, and so on). Now it is doing something new, and that something becomes self-motivating. The infant stands whenever it can, until standing is easy and it tries to walk, which itself becomes self-motivating. Once the infant masters walking, it runs; once it can run, it hops; and so on. Watch an infant who has managed to get into an adult's chair for the first time; it is safe to say that the child will repeat the action again and again.

Consider a man who begins work in a furniture factory to earn money to buy food and to satisfy other basic needs. Years pass and his skill in his craft grows, as does his salary. Then times change and the public is not willing to pay the high price charged for finely made furniture. The factory changes to a piecework pay system and the premium is thus placed on quantity, not quality. Yet, the craftsman will not hurry his work; although his income suffers, he still takes the time to do the best job he can. His work, originally done for money, has become functionally autonomous; it is done for its own sake.

In these cases, activity is initially done in the service of a basic motive, such as an instinct or drive, but it becomes autonomous—free of that motive. The connection with the earlier motive is thus historical but not functional. In our lives and in the behavior of animals there are countless instances of similarly autonomous motives, and it is difficult for the drive or instinct theories to account for them.

One example cited by Allport has been rediscovered and termed the contrafreeloading or the Protestant ethic effect. This effect was discussed in Chapter 5. It occurs when we train a pigeon to peck a key or a rat to press a lever and then make free food available. Even though the food is placed in a dish right next to the animal, it will still "do its job," so to speak, and peck or press the lever much as it did before the free food was available. Why is this? Well, it only occurs if the animal has a fairly extended history of pecking or pressing for food. Originally there is no question that the animal works solely for the grain or the food pellet produced, but is it possible that working becomes functionally autonomous? I have seen cases in which a pigeon pecked normally when its behavior was reinforced with grain according to a fixed-interval schedule. During the early part of each fixed interval, the bird escaped from the box it was in and walked around its end to the food hopper where it ate freely. It then returned to the box and pecked as usual until the end of the interval and the delivery of reinforcement. Had the bird not gained unusual amounts of weight, which led to an investigation, no one would have been the wiser, since the bird's record of pecking was completely normal. Is this analogous to the furniture maker? If not, why did the bird return to "do its work" so regularly?

The best example of functional autonomy is detectable in your own behavior every time you study for an exam or work on a paper while you are tired, hungry, and cold. Why do you do it? Is it because of a secondary reinforcer in the form of a good grade to come? Such a derived motive depends for its power upon attention and praise associated with good grades, which in turn has been paired with mother and father, and ultimately with food, water, and other basic needs.

How could that be true? How could such an acquired motive be stronger than the primary motives that torment you as you work? How can a motive remotely connected with food, sleep, and comfort be so strong that you work on while hungry, sleepy, and uncomfortable? Your motive for working has become free of basic needs, although it may have depended upon them when you first worked.

Allport points out that all of our activities do not become self-perpetuating; the infant does not go on walking endlessly for the rest of its life. Activities that are self-motivating are "habits in the making"; once we perform them reasonably well they occur only in the service of other motives. The infant may walk for the sake of walking, but we walk to get somewhere or to provide exercise and entertainment. The motivating character of nonperfected habits is what marks athletic, scientific, and artistic endeavors. One can never run the perfect mile, swim the perfect backstroke, perform the ultimate experiment, or write a perfect essay or poem, and we may therefore spend a lifetime trying.

Harlow's Case Against Drive

Harry Harlow spent many years running the primate laboratories at the University of Wisconsin and many readers must be aware of his work on "mother love." Some may be aware of his work demonstrating learning set, or "learning to learn." Along with these things, Harlow often and caustically criticized drive theory over the years, arguing for the far greater influence of external stimulation as the determinant of motivation.

Harlow launched strong attacks on drive theory in two papers published in 1953. He criticised the belief that biological needs are significant bases for motivation, and that so-called acquired needs are derived from them. Thus, unlike Allport, Harlow doubted that physiological drives play a major role in motivation, even in infancy. The following list highlights the main points of Harlow's criticism:

1. The human fetus responds to tactual stimulation before it has had any opportunity to experience hunger or thirst. Such biological needs are therefore not the basis for later needs for contact, as shown, for example, by his infant monkeys and the famous "cloth mother."
2. We routinely act *in spite of* hunger, pain, sex, temperature, and other basic needs; it is strange therefore to view our actions as ultimately dependent upon such things.
3. Most of us have never known true hunger or thirst; such drives are therefore largely irrelevant to our experience.
4. Strong drives are inimical to most learning. For example, a food-deprived child will not learn faster; it will close its eyes and cry.
5. Saccharine, a nonnutritive substance, acts as a marvelous reinforcer, although it obviously reduces no biological drive.

Harlow believed that drive reduction played little role in learning and cited an example as proof. In his years of work with rhesus monkeys, he routinely fed them before the experimental session, even though food was to be used as a reward. During a session, correct choices by the monkey were reinforced with raisins, and errors were not. But rhesus monkeys have cheek pouches in which they typically accumulate a store of raisins, releasing them into their throats whenever they wish. Thus, when an error is made and no raisin received, the monkey just releases a raisin and rewards itself! Drive reduction occurs whenever the animal wishes it to and thus it should never learn. But it does learn, leading Harlow to say that "the Lord was unaware of drive reduction theory when he created or allowed the evolution of the rhesus." (1953a)

As the alternative to the drive theory of motivation, Harlow stressed the importance of external stimulation, leading to curiosity, exploration, and manipulation. Rats learn to press bars to explore a maze and chimps and monkeys eagerly manipulate toys and puzzles. Curiosity and exploration are the important motives, not hunger, thirst, and other so-called primary drives.

But how can Harlow refute the irrefutable argument we noted some time ago? Is it not true that from early in life we and other organisms learn that exploration and manipulation often lead to products that reduce basic drives? The curious animal finds the food and the incurious finds nothing, right? This is a difficult argument to counter, but Harlow felt that he had done so.

He pointed out that this argument, which explains exploration and manipulation as secondary reinforcers, cannot account for the extraordinary persistence of such behaviors. Monkeys have manipulated mechanical puzzles for ten hours straight, with little sign of slowing down. One of Harlow's students, Butler, trained monkeys in a discrimination problem in which the reward was a 30-second view through a window, which allowed the animal to see other monkeys in the animal colony. This experiment was run for four hours per day, included 200 trials per day, five days per week, and ended because Butler could not stand to continue. During all of this time, the monkeys showed no sign of tiring of the task. Harlow suggested that no basic drive is so persistent and that 200 swallows would ban the strongest hunger.

If manipulation and exploration are conditioned reinforcers, then they should extinguish after numerous presentations without food, water, or other primary reinforcers. But they persist and persist, showing no decline in strength. A typical pattern in primates given a new toy or a new area to explore consists of an initial high rate of activity, followed by a decrease, and then a gradual increase up to some stable and amazingly durable final level. This is why he said that it is the drive theorists and not the monkeys who should be anxious!

Many treatments of Harlow's theory of motivation conclude that he was proposing the addition of a set of external drives to the set of internal drives stressed by drive theorists. Thus, we add drives to explore, manipulate, and touch to the standard drives of hunger, thirst, sex, warmth, and so on. This does not seem to be the message in his writings on the subject and, late in life, when he was asked at dinner, he made his opinion clear. According to Harlow (personal communication), he was not proposing to add external drives to the list of basic drives; he was arguing that physiological drives are almost wholly irrelevant and that motivation is dependent upon external drives—period.

4. OTHER ASPECTS OF HULL'S WORK

Aside from the basics of Hull's theory, covered above, the most important aspect of his work was the amazing influence he had on those who became his students and collaborators. Extremely capable people, such as Kenneth Spence, Neal Miller, O. H. Mowrer, Frank Logan, and others spent extremely productive careers in promoting what was essentially Hull's cause. This is not to say that all agreed with Hull; each disagreed on a number of fundamental matters. But all agreed in the general program that Hull proposed; psychology was to be the objective analysis of behavior in S-R terms and investigations were seen as the testing of hypotheses. This way of looking at things is still very popular today, especially since each of Hull's followers produced more students of his own and thus a significant number of current experimental psychologists trace their ancestry to Hull, in a manner of speaking. We will briefly discuss the contributions of Kenneth Spence and Neal Miller, two of Hull's best-known followers. In addition, we will discuss David McClelland's work; he is not widely thought of as a follower of Hull, but his method for assessing needs (for example, for achievement) is based on Hull's theory.

Kenneth W. Spence's Contribution

Spence did his doctoral work at Yale, where his research was directed by Robert Yerkes, not by Hull. But there is no doubt that Hull had an enormous influence on Spence and that Spence contributed greatly to Hull's theory. Spence later worked at the University of Iowa and then at Texas, where he died in 1967. His major contributions were his theory of discrimination learning, which is still current, his interpretation of inhibition, and his emphasis on incentive motivation rather than biological drive.

Discrimination Learning and Transposition Spence proposed his account for discrimination learning in 1937 as a counter to the Gestaltist Köhler (e.g., 1925). Köhler claimed to have shown that discrimination learning consists mainly of learning relationships among stimuli, rather than absolute values. Thus, we learn *darker* or *bigger*, rather than specific values of darkness and size.

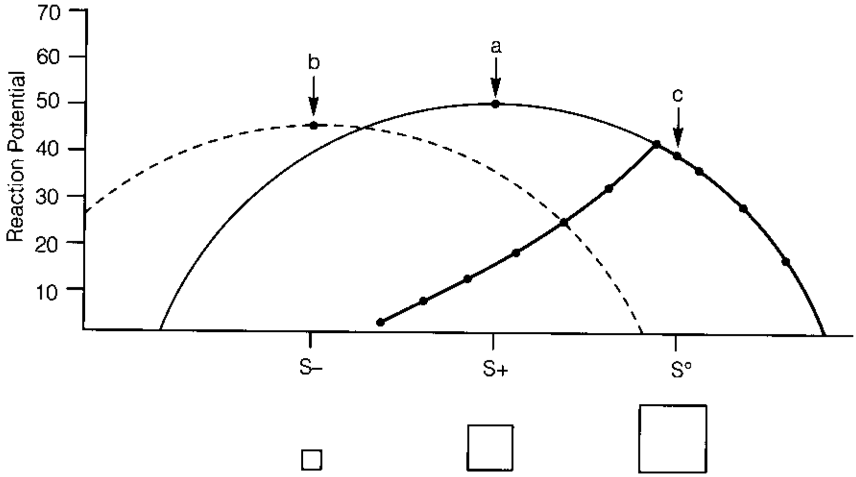


FIGURE 6.5 The Y axis scales tendency to respond and the X axis depicts a continuum of square size. The broken line represents tendency to not respond to S –; its form shows the range of generalization. The solid line centered at S + (a) shows the tendency to respond to S + and to other stimuli on the continuum. The diagonal line represents the algebraic sum of the two concave-downward curves. As is apparent, the tendency to respond (Reaction Potential) is greatest at S°.

Consider Figure 6.5. Suppose that a subject were trained to respond to the middle-sized square and not to the smallest square. What would happen if the subject were given a choice between the middle and the largest squares? In such problems, subjects ranging from chickens to children chose relationally. In this case, the subject most likely would choose the larger square; what the subject had learned originally was to choose the larger of the two squares when the choice had been restricted to the two smallest. Given a choice between another two, *transposition* occurs, meaning that the response is based on the relationship of size (larger).

Köhler and others stressed such data as evidence that we do not learn to react to specific stimuli; we always respond to relationships, such as warmer/colder, larger/smaller, and brighter/darker. This exemplified the Gestalt emphasis on innate organizing mechanisms (which we will examine in Chapter 7), and the fact that it occurred in chickens showed that it was a fundamental ability. For Hull (1943), Gestalt theory was a "doctrine of despair" and "philosophical fog." Spence was to account for transposition in Hull's terms.

Spence's explanation was simple and seemed to remove the need to appeal to mysterious learned relationships. According to Spence, what appears to be transposition can be explained as the simple effects of stimulus generalization. Consider Figure 6.5 again. Suppose that during the initial training the subject learned to respond to the middle square and that the strength of this tendency (${}_SH_R$) is indicated by point *a* in the figure. The curve on which that point lies represents the effect of stimulus generalization, spreading with decrement from *a* in both directions along the stimulus dimension of square size. Similarly, suppose that a tendency to not respond (${}_SI_R$) develops at *S*– and that its strength is represented by point *b*. Again, this inhibitory response tendency spreads in both directions.

Since these overlapping gradients represent opposed tendencies—to respond and to not respond—the tendency to respond to any value of the square-size dimension is the algebraic sum of the gradients at that point. Thus, when we pres-

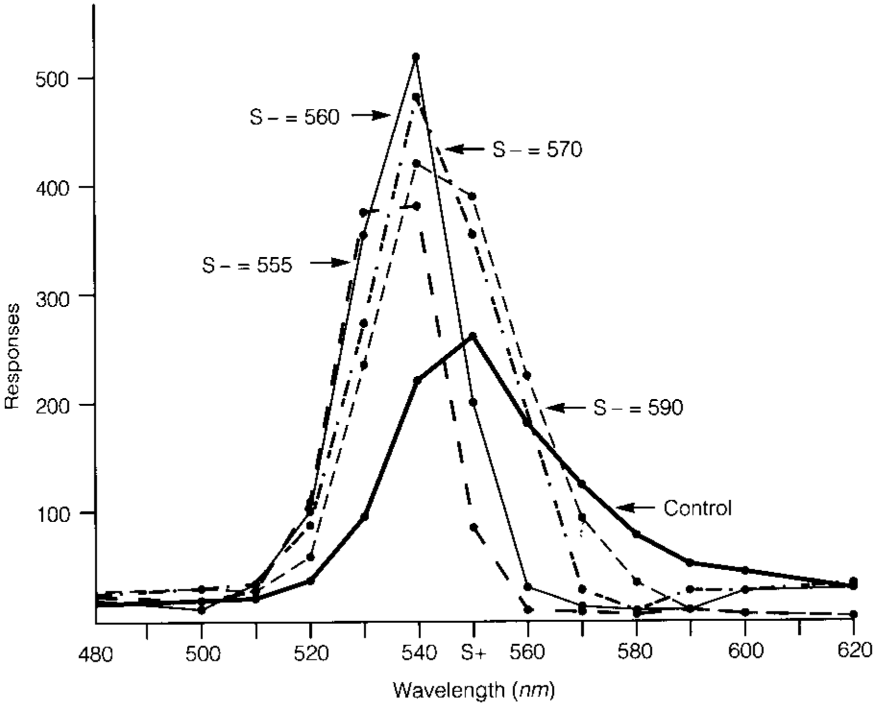


FIGURE 6.6 Results of Hanson's peak-shift study. The figure shows generalization gradients obtained during extinction testing for five groups of subjects. S+ was always 550nm and S− was either 590, 570, 560, or 555nm. The control group was trained only with S+ (550nm).

ent the old *S*+ along with a new stimulus, the large square *S*, the net tendency to respond to the new stimulus is greater than that corresponding to *S*+. The subject will respond (or respond more) to the new *S*. What appears to be the learning of relationships, evidenced as transposition when the new large square is presented with *S*+, is merely the result of learning to respond (or not) to specific values and the summing of associated generalization gradients. The "configurationalists," as Spence (1937) called the Gestaltists, were answered!

The Peak Shift and Gradient Summation Other research has lent support to Spence's model, although it does have failings (see Mackintosh, 1974). One conspicuous source of support for the theory in general is the peak shift, a phenomenon that seems made to order for it. Peak shift was first reported by Hanson (1959), who trained groups of pigeons to peck a disk illuminated with a hue of 550nm (greenish yellow), generated by a monochrometer. Pecks were reinforced occasionally with food, and one group, the control subjects, were then given a generalization test. During the test, the training stimulus was presented for 30-second periods along with twelve test stimuli, ranging from 480nm (blue) to 600nm (red). In Figure 6.6, the gradient labeled *control* shows the rates of response to each of these stimuli, averaged over the test session. It should be noted that this test was carried out in extinction; that is, no food reinforcement was given for responding to any of the stimuli. The logic was that such a test provides a measure of the tendency to respond to each test stimulus, as a result of the previous training to respond to 550nm ($S+$). The control gradient is thus a gradient of stimulus generalization.

Other groups were trained differently before the generalization test was given. Four discrimination groups were presented with a random series of $S+$ (550nm), along with a second stimulus ($S-$). Food was never associated with $S-$ and training was continued until a discrimination criterion was met. This required different amounts of training, since the $S-$ for each group was different; it was either 555, 560, 570, or 590nm. Now, 590nm is yellow enough to be quite easily discriminable from that of 550nm, at least for a human observer. But 555nm is virtually indistinguishable from 550nm. If simultaneously presented, we can distinguish them, but if presented successively in an unpredictable sequence, they are very difficult to distinguish. (Actually, Hanson found that his birds could distinguish differences in wavelength as little as one nm, so the task was evidently not impossible.)

The famous results of Hanson's test appear in Figure 6.6. Note that the gradients for the discrimination groups (555, 560, 570, 590nm) all show peaks at stimulus values different from 550nm, the old $S+$; only the control group showed a peak there. And note also that the degree to which the peak was shifted depended on its distance from $S+$, the degree of shift successively greater in the gradients for the 590, 570, 560, and 555nm groups.

Hanson considered the detailed predictions that Spence's model would make in such a situation and found that all were confirmed by his data, except one that is relatively unimportant. That is to say, the summation of hypothetical gradients of excitation around $S+$ and of inhibition (tendency to not respond) around $S-$ accounted well for the outcomes of the generalization tests.

The salient failure of Spence's model lay in its failure to account for the overall area of the gradients. Thus, if the discrimination gradients represent the algebraic sum of an excitatory gradient around $S+$ and an inhibitory gradient centered at $S-$, why are the postdiscrimination gradients all higher or larger than the control gradient? Can subtraction lead to an increase in something, in this case total responding?

Spence never took into account the effects of training procedure, and he was not aware of what we now know as behavioral contrast. As a matter of fact, Hanson was not aware of it either, since Reynolds's (1961a) report was yet to come. We will discuss behavioral contrast later; for now, note that Hanson's data seemed to lend strong support to Spence's model.

Inhibition and Frustration Spence suggested in his 1937 paper that the inhibition that came from nonrewarded responding and that produced the gradients of inhibition around $S-$ was not due to the accumulation of I_R and the development of conditioned inhibition ($_SI_R$) as responding to $S-$ ceased. Rather, he proposed that inhibition was due to *frustration*, a reaction produced when responding occurs and a reward is anticipated but is not received. Spence carried this idea further in the 1950s and 1960s. Abram Amsel and Allan Wagner continued to argue that the failure to be reinforced for behaving does not work in the passive way that Hull proposed.

Suppose that you are doing something that has led to food or other reinforcement in the past. You are working for wages, dieting to lose weight, or studying to do well on an exam. In the past, these actions enabled you to gain money, lose weight, or get a good grade (respectively). In Hull's terms, you are following the stimuli of the world sequence, in some state of need, and expending energy as you work. If reinforcement occurs, it reduces the (secondary) drives for money, weight loss, and achievement. This leads to an increase in $_SH_R$ (and thus, $_SE_R$), which easily exceeds the I_R that accumulates with effort expended and the $_SI_R$ that increases when you slow down work. We learn to do things that end in the reduction of a primary or a secondary drive because the increase in $_SH_R$ and $_SE_R$ is greater than the inhibitory influences involved (I_R + $_SI_R$).

Spence suggested that the failure to be reinforced has a different and a greater effect than Hull believed. In a situation in which we have experienced reinforcement in the past, part of our activity is energized by the fractional anticipatory goal response, r_G–s_G. This is simply a way of saying that previous reinforcements have led to such anticipatory goal responses. We expect a reward, and this is accounted for by the fact that we are accustomed to a reward when the sequence ends, and as we go through the sequence we are already making little r_G's: We are receiving the money, seeing the scale in the morning, and receiving the exam grade. We anticipate the reward just as that rat did; the rat, when following its normal route to food, salivates, licks its chops, and smells what it expects to be at the end of the trip. What happens when the customary reward is not there? Spence, later followed by Amsel and others, suggested that nonreward in the context of reward produces a strong response, termed R_F, or the primary frustration response.

R_F, like R_G, becomes attached to stimuli that precede it, and thus fractional anticipatory frustration responses may begin to occur. These responses, r_F's, produce stimuli just as r_G's do; hence, we have r_F–s_F's occurring during the sequence. Nonreward may at first slow us or the rat down; we cannot be certain that the goal object we are expecting will be there on that trial. But it often is, and the little s_F's act as do any other stimuli; they are present during drive reduction, so they are attached to the responses that occurred prior to drive reduction. They thus add to the total stimuli attached to each response and increase the total $_SH_R$ for each response.

Spence suggested that this means that subjects rewarded 100 percent of the time may not perform as well as subjects that are not given rewards on every trial. This has been shown to be true in a number of experiments, such as that by Goodrich (1959), whose results are displayed in Figure 6.7. Goodrich trained two groups of rats to run down a runway for food placed in the goal box. Rats in the 100-percent group found a food pellet in the goal box on every trial, whereas those in

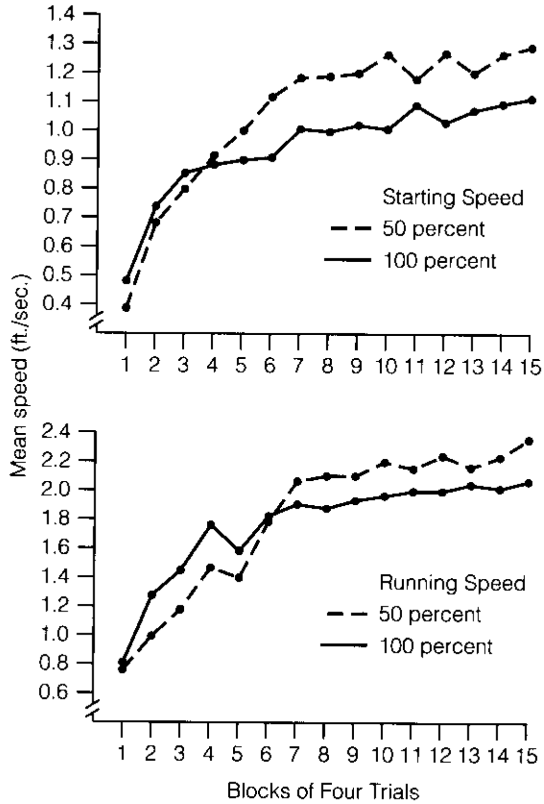


FIGURE 6.7 Results of Goodrich's experiment II. Mean starting and running speeds for groups reinforced on 50 or 100 percent of trials (dashed and solid lines, respectively).

the 50-percent group found a pellet only half the time and there was no telling which times they would be. As training progressed, those in the 100-percent group increased their speed of running the alley faster than did those in the 50-percent group. The latter group was fed only half the time, so $_SH_R$ would increase more slowly and nonreward was producing frustration responses, which would interfere with running. But later in training, the 50-percent group caught up with and surpassed the 100-percent group. Evidently, the fact that the rats continued to run means that s_F became attached to that behavior and gave them the final edge over the 100-percent group.

Amsel (1962) showed how the frustration effect (FE) and $r_F - s_F$ could account for the partial reinforcement effect (PRE), or the fact that subjects that are rewarded on only some trials go on responding longer when no reward is given than do subjects rewarded on every trial. The explanation is essentially that given above. Wagner (1963) similarly emphasized the effects of frustration, suggesting that courage consists of action done in the face of frustration. When we or the rat head for a goal that may or may not be there, and $r_F - s_F$ has not become attached to our responses and it thus just slows us down, we are displaying courage.

Incentive Motivation A number of Hull's critics showed that learning occurred in the absence of reward, a finding clearly in violation of Hull's postulate IV. Spence invented *incentive motivation*, which Hull symbolized as *K* (for "Kenneth"). We will show how K was used in this regard in the next chapter, where we consider Tolman. For now, we will just look at what it is and what it does. K, or incentive motivation, refers to the motivating effect of the amount and quality of a reward. A dish of bran mash or a thick chocolate milkshake are clearly different from a small, dry pellet and a glass of diet root beer, and in fact, their effects are different.

By the 1950s, Spence also greatly modified Hull's theory by proposing that habit strength (${}_SH_R$) does not depend upon reward in the form of drive reduction; rather, ${}_SH_R$ just increases in strength with repetition, and performance is the energizing of such habits by drive and incentive. This means that learning depends only upon practice; you can see that Spence had come to agree with Watson and Guthrie!

Finally, Spence proposed a biological basis for K, which is quite reasonable. Remember that K represents the motivating influence produced by the amount and quality of the reinforcer. Imagine the milkshake and the diet root beer, which surely differ in quality. They also differ in the reaction they produce. The root beer doesn't produce much, while the thought of the milkshake makes one salivate, swallow, and move the tongue around. These are fractional antedating goal responses. The better the goal object, the bigger the little $r_G - s_G$, since the bigger was the R_G when such objects were encountered in the past.

Therefore, the amount and quality of the reward produces a bigger physiological response from us (in the form of r_G), and the way it feels to make r_G (that is, s_G) is more noticeable. Since K also depends upon the amount and quality of the reward, why shouldn't K be simply s_G? The sum of the feedback produced by r_G's is what we mean by incentive.

Kenneth W. Spence worked long and hard for Hull and later for his own revised Hullian theory. Hull was mindful of Spence's assistance in preparing the preface to *Principles of Behavior* (1943), although at that time he was not certain of Spence's name. Hull wrote, "To Kenneth L. Spence I owe a debt of gratitude which cannot be adequately indicated in this place." Let us see how the thought of Hull and Spence influenced the study of human motivation, as reflected in the work of McClelland.

Need for Achievement and Other Needs

Recall that Murray compiled an inventory of the needs of Harvard undergraduates in 1938, categorizing them as viscerogenic (primary) or psychogenic (secondary). He also proposed methods for the assessment of degrees of need, such as the *thematic apperception test*, or TAT. Subjects were presented with a variety of pictures—such as two men working on what appears to be a machine, a boy gazing out over an open book, or a father–son conversation—and were asked to write a brief story about each picture. The stories were then analyzed to gauge the kind and degree of motives possessed by the subject. Is this sensible?

This is the rationale for the TAT, which David McClelland and his associates have used extensively (e.g., McClelland, Atkinson, Clark, & Lowell, 1953). They assume that a cue arouses pain, pleasure, or other reactions because it has been paired previously with affect. For example, the pleasures of eating are accompanied by all sorts of cues, such as the sight and smell of food. When one of these cues appears by itself, it produces part of the affect present when eating last took place. McClelland (see Figure 6.8) and others viewed the partial reaction produced by the cue as an instance of Hull's fractional anticipatory goal response. The partial reaction produced by the cue acts as a motive for the full affect, or Hull's goal response (R_G). McClelland, 1985, discusses this interpretation more fully.

Here is where the TAT comes in. Depending upon an individual's motivational state at the time, the content of the picture descriptions will contain fractional goal responses (r_G) produced in the same way that a picture of food produces salivation in a hungry subject! In a 1949 study carried out with sailors deprived of food for one, four, or sixteen hours, McClelland and his associates were able to distinguish the one- and four-hour subjects from the sixteen-hour subjects, based on food-related themes appearing in their TAT responses.

This demonstration was used as evidence that the TAT really *can* assess levels of motivation, and subsequent studies attempted to use it to measure needs for affiliation, power, aggression, and other motives. The real effort has been directed at the assessment of nAch (need for achievement), however, since many view this as an indispensable quality if one is to succeed in life.

McClelland, Clark, Roby, and Atkinson (1949) tried to show that the TAT could accurately measure nAch in an experiment carried out with over 200 male subjects in the Boston area. During a 50-minute class period, subjects were given seven tasks, each taking three to four minutes to complete. The tasks included anagram problems and motor problems requiring that the subjects write backwards as quickly as possible, for example. Some subjects were given relaxed instructions, stating that the tasks were being tried out and their performance on them was nothing to worry about. The other groups were given quite different instructions:

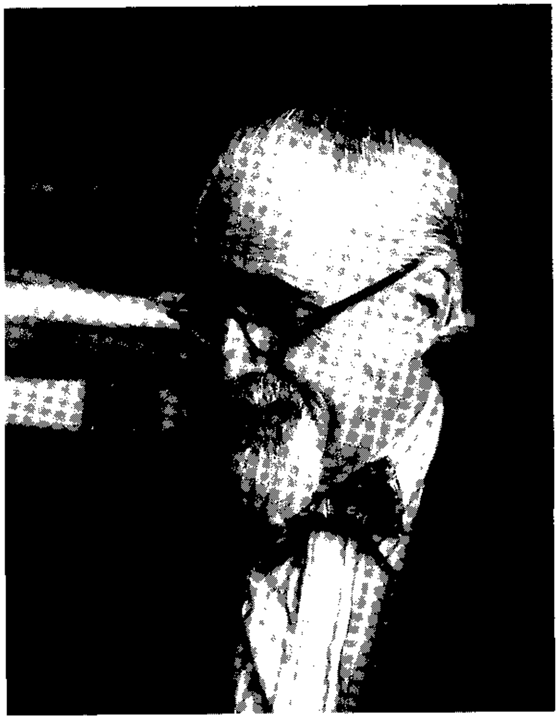


FIGURE 6.8 David McClelland 1917–. Psychologist best known for his work assessing nAch (need for achievement). *Photo courtesy of David McClelland*

> The tests which you are taking directly indicate a person's general level of intelligence. These tests have been taken from a group of tests which were used to select people of high administrative capacity for positions in Washington during the past war. Thus in addition to general intelligence, they bring out an individual's capacity to organize material, his ability to evaluate crucial situations quickly and accurately; in short, these tests demonstrate whether or not a person is suited to be a leader.

They went on to say that the Navy was conducting these tests to determine which universities are turning out the best leaders, and scores supposedly obtained by Wesleyan University students were shown to some groups.

One group was then given the tests and shown that they all performed far below the level of their Wesleyan counterparts. This was appropriately called the "failure" group. The other two groups were dropped because of what the experimenters interpreted as odd behavior (!). This was the "success-only" group whose members were told that they had performed above the level of the Wesleyan subjects. The "ego-involved" group consisted of subjects who were not told the scores of the Wesleyan subjects. Finally, one group ("success/failure") was allowed to taste success by being given very low norms (Wesleyan scores) on the first test, only to fail badly on the second, for which they were given very high norms.

All of these subjects were then asked to write stories about four TAT pictures and these were analyzed for nAch. How was that done? The raters counted up the images and themes that referred to achievement in the stories. This included references to needs, impediments, effort, goals, affect, and helps and hindrances. For example, a response might include, "The men in the picture are trying their best to fix the machine and it is a difficult job and time is short, but they will feel proud when they achieve their goal."

As you might expect, the relaxed group scored lowest in nAch, the failure group scored higher, and scores of the success/failure group were the highest. Both of the latter groups had been read the achievement-inducing instructions, and the success/failure group had been allowed that taste of achievement which aroused nAch even more, especially after their subsequent "failure." The success-only group and the ego-involved group were dropped; the former group showed too much nAch, while those in the latter group were so tense that their TAT responses were "uninterpretable."

Since it is possible to assess nAch, it would be nice to know what it is that is being assessed and whether there is any relation between nAch scores and other kinds of performance. Murray initially defined nAch as the motive to "do as well as possible as quickly as possible and to outdo others." One can easily see what is meant by that: *Competitiveness* is a close synonym. But do TAT ratings of nAch correlate with performance in general? McClelland assures us that nAch predicts a variety of forms of achievement, including the achievements of entire nations and the success of businessmen.

Neal Miller's Contribution

Miller obtained his doctorate at Yale as a student of Hull and immediately traveled to the Vienna Psychoanalytic Institute, where he spent several months of 1935. The purpose was to learn as much as possible about Freudian therapy; Hull intended to incorporate whatever he could of psychoanalysis into his theory. Dollard and Miller (1950) published a book that more or less accomplished that aim.

From 1936 to 1966 Miller was a member of the faculty at Yale and thereafter was associated with the Rockefeller University in New York City. Although Miller has not proposed major innovations in theory, he masterfully carried out research and contributed greatly in several areas. We will consider three of his achievements.

The first and most important is his 1941 book with Dollard, *Social Learning and Imitation*. This was not only a simplified version of Hull for the masses but also the beginning of social learning theory, a position now associated with Albert Bandura. Secondly, he showed how Hull's principles could apply to conflict, as stressed by Lewin and other Gestalt-influenced psychologists, who explained such phenomena in terms of fields of attraction and repulsion, a view clearly repulsive to Hull. Thirdly, he performed a classic experiment showing that fear could be viewed as an acquired drive.

Social Learning Theory Miller and Dollard (1941) greatly simplified Hull's mass of postulates and theorems to four basic elements: drive, cue, response, and reward. Drives make us act, the act is a response, the response occurs in the presence of a cue, and rewards that follow the response reduce drives and connect the response to the cue. This is essentially what a barebones caricature of Hull's (or Thorndike's) theory asserts and it has its uses. Miller and Dollard provide many examples of applications. For example, the following amusing passage explains why we like to hear ourselves talk:

> Tom heard himself crying and babbling repeatedly just before major reduction of primary drive occurred. Hearing himself babble, therefore, acquired a secondary rewarding character. Hearing someone else talk is sufficiently like hearing oneself cry or babble to tend to evoke the same relaxation responses. Thus, hearing his own vocalizations came to indicate to the child that the goal was in sight. The same logic also applies, of course, to the mother's footstep, the stimulus pattern of her voice, face, dress, and the like. (Miller & Dollard, 1941, p. 139)

This account of secondary reinforcement is, of course, Hull's account, and it plays a part in the explanation of imitation, which led directly to current views in social learning theory. All of us who have been through the public education system realize the importance of imitation, or the influence of modeling; this determines in large part our values, our heroes, and our clothing and hair styles. Is imitation an instinct, as William James (1890) and McDougall (1908) felt, or is it learned? The matter is by no means settled, but Miller and Dollard proposed a theory that can account for imitation in terms of Hull's principles, and Bandura holds a somewhat similar view, as we will see.

Miller and Dollard provided evidence that imitation is a learned behavior, dependent upon reward (drive reduction), just as other behavior is learned. A simple example involves a child who happens to run to the door to greet Daddy at the same time that an older sibling runs to the door. the older child may have some expectation about what Daddy may have brought, but the younger child just happens to do what the older did on that occasion. The father has candy for both of them and running to Daddy at the door is thus rewarded. As Miller and Dollard put it, this establishes such activity as matched-dependent behavior. The matching, or copying, of the older child's behavior becomes a cue for such behavior, dependent upon the consequences of such imitative behavior. And it is easily interpreted in terms of drive (the younger child's appetite for candy), cue (the older child's running), response (doing what the older child does), and reward (the candy from Daddy).

Miller and Dollard presented data from a series of experiments, first using rats as subjects, and then showing parallel results with children as subjects. They demonstrated the learning of imitation (or of nonimitation—doing other than the leader does), as well as the generalization of imitating to new similar leaders. They also showed generalization to new situations: A leader imitated in a two-choice problem is imitated in a four-choice problem, whether the subjects are rats or children. Children also quickly learned to discriminate models; "good" models were rewarded and imitated, while "bad" ones were not rewarded and therefore were not imitated. In some cases the good model was a younger child and the bad one was a Yale University graduate student, but fourth-grade children were still quick to learn to imitate the child. Finally, generalization to quite dissimilar situations was shown. Imitative behavior consisting of picking one of two boxes generalized to pulling a ring.

Miller and Dollard noted that good models tend to be older, of higher social status, more intelligent, and technically competent. It is also important that the imitator pay attention to important aspects of the leader's behavior and that the imitator have the cue/response connections available to perform the behavior required. This is what Bandura (1976) calls the capacity for "motoric reproduction." Miller and Dollard also felt it was important that the model be "correct"; as they pointed out, we do not imitate those who make mistakes often. We discriminate leaders worth imitating from those who are not worth it.

Miller and Dollard stressed repeatedly the importance of generalized imitation; what is learned is not the performance of specific behaviors in specific situations with a specific model. In fact, "the wish to match behavior with another can itself become a secondary drive." This point of view was taken up by Baer (e.g., Baer & Sherman, 1964) and it makes a lot of sense. Throughout life, we find that when we do as specific ("good") models do, we benefit. In time, we feel comfortable doing as such models do and uncomfortable when we do otherwise. Needless to say, a good model is "good" only in some situations. We may not imitate the eating habits of our swim coach, but we are apt to attend to and imitate his or her swim strokes.

Bandura and Social Learning Theory Albert Bandura was educated at the University of Iowa during the period when Kenneth Spence was a faculty member. Although Bandura is often cast otherwise, his thinking has shown Spence's influence; his research is clearly similar to Hull's and this may account for some of the controversies that have arisen between Bandura and followers of Skinner (see Chapter 8).

Bandura's classic research appears in too many other texts to warrant giving it much space here. In 1965 he published the famous Bobo doll study, showing that imitative aggression toward an inflated toy depended upon the consequences received by adult models whom the children watched attacking the doll. Punished models resulted in less aggression on the part of the children, although when queried the children could certainly tell what the model had done. This finding and other aspects of the results of that study were mighty impressive to Bandura, who subsequently proposed a new version of Miller and Dollard's adaptation of Hull, which has become known as social learning theory (Bandura, 1986, renamed his version social cognitive theory).

Incredibly, Bandura (e.g., 1977) attacked the generalized-imitation theory of Miller and Dollard and of Baer and Sherman (1964), claiming that it requires that we should imitate everyone. He also claimed that the theory requires that imitative behavior occur immediately; if imitation occurs an hour later, the theory is wrong! Additionally, the imitative act must be followed immediately by reward, according to that theory. Or so wrote Bandura.

After an unfair critique of Miller and Dollard (via Baer), Bandura proposed his alternative theory. He emphasized the fact that imitation need not occur immediately, and that when it does occur it need not be accompanied by conspicuous reward. Instead of imitation as a generalized tendency to do what certain others do, Bandura stresses the processes that must be responsible. Hence, he proposes attention, memory, motoric reproduction, and reinforcement as basic requirements. Interestingly, reinforcement is viewed in a way similar to that of Hull and Spence, as self-generated anticipatory behavior, basically the same as the fractional anticipatory goal response, although Bandura would not use these words.

What Bandura thinks is important and unique is his emphasis on the role of vicarious experience, symbolic activity, and self-regulation via cognitive activity. We will discuss some of this in Chapter 8, but it should be pointed out here that the gist of Bandura's theory is Hullian, although Bandura uses different terms. Both theorists stressed what was later called molecular treatments of behavior—that is, emphasizing discrete stimuli, responses, rewards, cognitions, and so on, rather than larger, molar, variables (this was pointed out by Malone, 1990).

Conflict How do we deal with the fields of forces that seem to be operating as we debate whether to go to our room to study or to go with the gang to a movie? It often seems that we are drawn by separate forces in such situations. In other situations, we have other conflicting forces. Suppose, for example, you have a toothache and are told you need a root canalization (root canal). Others have told you the nature of the procedure and it seems very difficult to submit to it, although we know that it is painless and that it may save the tooth. The tendencies to approach and avoid such an operation seem to be in conflict.

Such conflicts may also be cast in terms of Hull's fractional anticipatory goal responses, although Miller did not do this. He did show that such conflicting response tendencies could be measured as behaviors and that we could predict the outcome of such conflicts. Briefly, what Miller did (e.g., 1944) was to train rats to run down an alley for food, and, once he established the tendency to run, he attached a strain gauge to the rat with a harness so that he could measure the force exerted by the rat as it ran. As the rat ran toward the goal of food, its pull on the strain gauge increased and Miller had a measure of the gradient of approach toward the food. The rat's pull on the strain gauge steadily increased as it neared the food.

Next, Miller shocked the rats at the end of the alley, which contained the food, thus making that area aversive. Again, with a harness and strain gauge attached to the rat, he measured the tendency of the animal to move away from that area. In this case, the pull was once again strongest near the end of the alley and became weaker as the rat moved further from the end box. This was the avoidance gradient.

Miller now had a measure of the tendency to approach the end box, because of the food that had been received there, and of the tendency to avoid it, because of the shock that had been given there. The avoidance gradient was steeper, ending closer to the end box, and the approach gradient was relatively shallow, extending farther from the end box and thus closer to the start box. Figure 6.9 presents Miller's results.

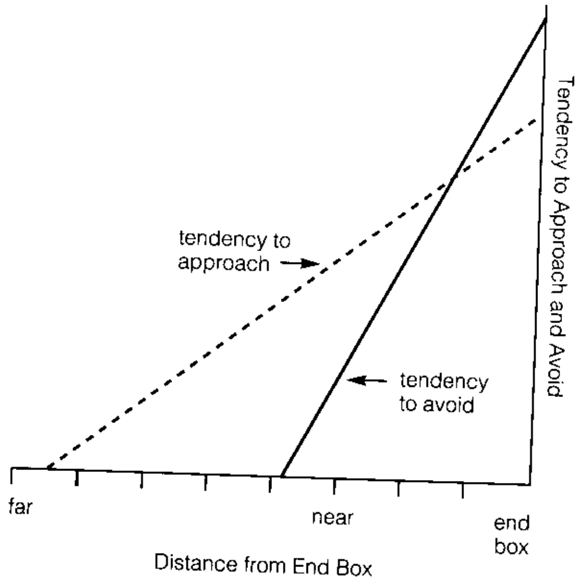


FIGURE 6.9 Miller's hypothetical gradients of tendency to approach and to avoid, plotted according to distance along a straight runway.

Suppose that we take the rats and place them in the start box. In theory, they should wander around until they moved into the approach gradient, at which time they should start for the goal box, accelerating as the gradient rises. They should then hit the avoidance gradient, at which time they should slow down, move about, and eventually move back toward the start. Then, the approach gradient should set them moving back toward the end box, accelerating until they reach the avoidance gradient.

Miller's rats did better than that. At the point where the gradients of approach and avoidance cross, the net tendency to approach or avoid is theoretically zero. Now, few researchers have rats or other subjects that obey theoretical principles, but Miller did. He reported that his rats advanced to the point where the approach and avoidance gradients crossed (and the tendency to move forward or backward was balanced) and then stopped! Here was the vague field theory of Lewin translated into Hull's quantifiable terms and experimentally verified.

Fear as an Acquired Drive Hull, as well as many other theorists, assumed that money, attention, and all of the other things that act as reinforcers but that do not satisfy biological (primary needs) gain their power simply by their past association with primary reinforcers. Miller's 1948 experiment is often cited as evidence that such is the case. Miller showed that stimuli paired with painful electric shock became secondary aversive reinforcers and that they then acted as other reinforcers.

As an aversive reinforcer, shock may be used to motivate behavior. It then acts as *aversive drive,* meaning that it produces escape and avoidance behavior. It may also be used to reinforce behavior that eliminates or avoids it. Can it be shown clearly that stimuli paired with an aversive reinforcer can also motivate and reinforce behavior?

Miller's rats were placed in a two-compartment box, with one side painted white and the other black. The rats were placed one at a time in the white compartment and given ten trials with electric shock, coming from the grid on the compartment floor. On the first trial, the rat was placed in the white compartment and, after 60 seconds, it was shocked every five seconds for 60 seconds. If it ran into the black compartment, the rat was safe from shock, since there was no shock grid on the floor. On the second trial, the rat was again placed on the white side and shocked, this time after 30 seconds; again, it could escape by running to the black side. On both trials the escape to the black side was blocked by a door until the shock was turned on. During the remaining eight trials, the shock was on at the moment the rat was placed in the white compartment and the door was opened immediately so the rat could run to the black side and escape the shock.

As you might imagine, this experience made the rats less fond of bright white surroundings then they were to begin with (rats typically prefer darker to brighter areas anyway). Miller then placed each of the rats in the white compartment with no shock present to determine whether the white stimuli had gained fear-producing power. Not surprisingly, all of the 25 rats rushed to the black compartment. Thus, the white surroundings had gained the power of a conditioned aversive reinforcer.

Real reinforcers also strengthen the responses that produce them. In the case of aversive reinforcers, they strengthen behaviors that remove them and thus reduce fear. Miller closed the door between the white and black compartments and placed a small wheel on the door. The door could be opened if the rat turned the wheel a fraction of a turn. Would the rat, in its fear of the white compartment, learn to turn the wheel and thus escape to the black side?

In eight trials, in which a rat was placed in the white compartment and a turn of the wheel was required to open the door and escape the fear-producing stimuli, thirteen of 25 animals did turn the wheel and thus show that acquired fear acted as a reinforcer capable of producing the learning of a new response. A small bar was then placed in the box and the thirteen successful rats were given the opportunity to press it in order to open the door and escape to the black side. This they did, showing that a new behavior could be learned to escape the secondary aversive reinforcer.

This often-cited experiment shows that cues accompanying an aversive stimulus can gain fear-producing power, and new behaviors that produce escape from such stimuli will be reinforced. If only such evidence could be provided in the case of appetitive reinforcers, such as food, and the cues accompanying them, life would be much simpler. We will see in Chapter 9 that this has not been the case and that a lot of the support for the position on conditioned reinforcement maintained by Hull and his followers comes from research in which aversive reinforcers, such as electric shock, were used.

SUMMARY

Hull was the great systematizer and organizer who came at a time when the functionalists, the behaviorists, and the Gestaltists had pretty much displaced the old psychology of Titchener and the introspectionists. Perhaps Hull would have done well whenever he had come along, but the time seemed especially ripe for the sort of institutionalizing of psychology that Hull proposed. (Even today, perhaps, many contemporary psychologists would welcome the appearance of someone who could convincingly put order into the chaos of theories and the disputes of opposing groups, as Hull had done in his time.)

Hull proposed that, despite differences in opinion on other points, there was a broad concensus that living things, including ourselves, could be treated as machines and that behavior could best be analyzed in stimulus-response (S-R) terms. He further assumed that it was absolutely necessary to quantify everything and that it was possible to do so. We did not stress this aspect of his theory, but a reading of any of his works shows that he was a master of attaching numbers to habit strength, motivation, and other variables of his theory in a way that allowed him to make surprisingly accurate predictions. This ability was not shared by his followers, and such efforts did not continue long after his death.

Hull and many of his followers have said that the details of his theory were not particularly important; Hull believed that the hypothetico-deductive method was the key to progress. If we begin with a set of clear statements about learning and constantly test and revise them, we will surely improve our understanding of behavior, even if the set of postulates with which we begin is largely erroneous.

Hull's system was composed almost entirely of intervening variables, which were terms used to relate the diverse independent variables that seemed to covary with a set of diverse dependent variables. For example, a host of factors may lead us to eat, and the increase in eating may be assessed in terms of amount of food eaten, rate of eating, money spent for food, and so on. Hull represented the effects of all of the independent variables on all of the related dependent variables with single terms; in this case, the term is *hunger*, and in other cases it is ${}_SH_R$ or D or any of over a hundred other intervening variables. This aspect of Hull's theory was anathema to Skinner and is one of the many things that make Skinner's theory basically different from Hull's.

We showed how Hull explained complex phenomena, such as knowledge, foresight, and purpose in terms of simple habit mechanisms. Hull's account leaves out the color and zest of our experience (to which literature, poetry, and the rest of the humanities are devoted), but his account was intended to propose the basic mechanisms that underlie our behavior. He felt that movement-produced stimuli were the basis for knowledge and that chaining could account for foresight. He explained purpose and anticipation in terms of fractional anticipatory goal responses, an explanation that had a long history in psychology and that was adopted by many of his prominent followers.

Hull was always concerned with practical application, although he personally was not concerned with dealing immediately with what the public considers to be pressing problems. We must understand the basic determinants of the rat's behavior and our behavior before we can apply anything. But Hull did suggest in outline form ways in which important practical matters could be treated, and his students were more specific in suggesting practical applications. His seminars at Yale in the late 1930s interpreted the conflicts among nations, blackmail, the learning of speech, lying, rationalization, reasoning, logic, psychoanalysis, and malingering, all in terms of habits strengthened by obvious reinforcers.

The research program begun by David McClelland and his associates in the late 1940s and aimed at assessing nAch was a practical expression of Hullian thinking. Even in 1985, McClelland still saw merit in the approach of Hull. The social learning theory of Miller and Dollard showed how practical Hull's theory could be and how it could account for imitation in a plausible way. This account has been criticized by Bandura, although his alternative is also clearly derived from Hullian-like thinking.

The major criticisms of Hull lie in his insistence, despite disclaimers, on molecular (atomistic) analyses of phenomena. Opponents have charged that such a method assumes that there are some units of behavior and experience that are assumed in advance and that the true nature of behavior can be seen only after observation. Most current psychologists are similarly atomistic, however, so this is really not a strong criticism of Hull's theory.

Hull's emphasis on the hypothetico-deductive approach is easier to criticize, especially since such methods are not currently fashionable. The main reason for this comes from the history of work during the 1940s and early 1950s, when it became apparent that the method was unworkable in practice. It is not possible, as Hull tacitly assumed it was, to decisively test a theorem and therefore perform a crucial experiment. The assertion that all reinforcement depends upon the reduction of a drive was debated for 30 years after Hull proposed that it was so and, to an extent, the debate goes on. If one part of one postulate cannot be adequately tested for truth or falsity in almost half a century, one must question the worth of a theory that requires that such tests be made.

A final criticism of Hull may not be fair, given his aims and his desire to make psychology truly scientific. But his refusal to admit our private experience as a legitimate part of psychology was a break from his behaviorist predecessors and served to alienate a great many other psychologists much more than did Watson's insistence that we dispense with the terms of the introspectionists. Watson still left private experience as part of what we must explain, while Hull believed that it was unworthy of study. Since Hull's time, those theorists who called themselves behaviorists are assumed to deny the existence of private experience. We still feel this influence today.

Hull's students contributed greatly to his work, and we briefly considered the work of Spence and Miller. Spence's theory of discrimination learning is still with us and was a godsend to Hull in the 1930s, when the Gestaltists and others who sympathized with their general point of view opposed the analysis of behavior and experience into units of the kind that Hull proposed. His analysis of transposition in terms of the learning of individual habits generalized to stimuli lying on the same continuum was a stroke of genius at the time and has proven a difficult proposition for later workers in generalization and discrimination to disprove.

Spence also proposed that the effect of nonreinforcement was not a passive process, as Hull had proposed, but that it led to a reaction of frustration and that this reaction produced what Hull had called inhibitory effects. This view was elaborated by his students Amsel and Wagner, who were responsible for the great popularity of frustration theory during the 1960s.

Spence also was responsible for the invention of incentive motivation (K), introduced to deal with data produced by Tolman and his aides, which showed that learning occurs in the absence of drive reduction. Spence suggested that goal objects may produce fractional anticipatory goal responses in proportion to the magnitude and the quality of the goal object and that this may act as an added motivating factor, along with drive, to produce rapid learning.

Miller and Dollard attempted to show how Hull's general principles could account for a variety of human social behavior, particularly imitation. Miller also studied conflict situations using animal subjects and showed how one might measure the tendencies to approach and avoid goal objects. His 1948 study of fear as an acquired drive has become a classic.

GLOSSARY

Automaton A machine, or automatic device, built from parts that are known and the actions of which are understood. Hull suggested that we treat ourselves and animals as automata in order to avoid explanations for our behavior that rely on agents whose properties we do not understand. Thus, *purpose* and *knowledge* are understood only when we have built a machine that shows purpose and knowledge.

Aversive drive Stimulation that leads to activity to escape or avoid it. This commonly refers to electric shock and other things that produce pain. Hunger, which may be painful, is referred to as an appetitive drive, since the object that reduces the drive is viewed as pleasure producing, rather than as pain ending. Hull and his followers used the appetitive/aversive distinction, but it is surely vague and has been criticized widely. For example, when we do something to escape the cold, are we driven by the aversive drive of cold, or the appetitive drive for warmth?

Chain A sequence of behavior that is linked together (as a chain) by the consequences of each response. These consequences may be in the form of movement-produced stimuli or stimuli from outside, as when we recite a poem and each word or line acts as a stimulus for the next response.

Conditioned inhibition A negative habit, or tendency not to do whatever response was last done in the presence of the stimuli involved. Like positive habits ($_{S}H_{R}$), conditioned inhibition is reinforced by drive reduction. In this case, the drive reduced is reactive inhibition (I_R), which begins to dissipate when action slows or ceases.

Crucial experiment An experiment that yields results that clearly and unambiguously show that a hypothesis is true or false. There are many such experiments in the physical sciences, such as the Michaelson-Morley experiment, which convinced most observers that the theory that held that space is filled with ether was definitely untrue. Hull's hypothetico-deductive approach assumed that such experiments could be done more easily than is the case. Even in the physical sciences, such experiments appear relatively infrequently.

Dependent variable That which we observe or feel as a change in something as the result of some manipulation. The data of most experiments are the dependent variables; they are the effects that we wish to predict. For example, a period without food produces changes in dependent variables such as reported hunger and in the amount of food eaten once it is made available.

Drive Hull's term for all of the factors that motivate behavior. Hull believed that learning per se is not sufficient to produce action; drive is necessary to energize learning.

Drive stimulus Hull's conceptualization of biological drives in stimulus form (stomach contractions, and so on). If drives can be treated as stimuli, then they can enter into connections with responses, as do other stimuli.

Excitatory reaction potential Hull's intervening variable representing the tendency to behave, symbolized by $_{S}E_{R}$. It is the product of $_{S}H_{R}$ times drive, minus inhibitory factors. Reaction potential may be measured in terms of latency of response, amplitude of response, and resistance to extinction.

Frustration Spence's term for the reaction produced when no reward is received in situations in which it has been anticipated. Spence felt that this was the basis for inhibition. Amsel, Wagner, and others developed a theory in which fractional anticipatory frustration comes to act as an added motivator.

Fractional antedating goal response Also called the fractional anticipatory goal response. This is a partial goal response that may occur well in advance of the meeting with the goal stimulus. When someone is anxious to eat, fight, dance, or whatever, he or she is already making some of the responses that will occur when the goal activity begins. For Hull, the way it feels to make such anticipatory responses is the physical basis for what we call anticipation. Fractional antedating goal response is symbolized as $r_G - s_G$.

Generalization Stimulus generalization refers to the fact that we respond to a range of stimuli that are similar to stimuli to which we have learned to respond. For example, we may behave in the same way to policemen, even when they are dressed in uniforms unlike those to which we are accustomed. Response generalization refers to a behavior learned in a specific way that may occur in similar, but not identical form. Once we learn to button a sweater, for example, we may do so in somewhat different ways on every occasion that follows. Hull treated this as a case of generalization.

Goal stimulus Hull's term for reinforcers, symbolized by S_G. Such stimuli were assumed to be capable of reducing drives or secondary drives.

Habit Hull's intervening variable representing the effects of learning and symbolized by $_{S}H_{R}$. Habit strength depends upon reinforced occurrences of responses in the presence of stimuli. Each reinforcement added an increment of habit strength that was a function of the maximum habit strength possible (M), minus the amount of habit strength already existing.

Hypothetico-deductive method A method for discovering new knowledge, which begins by clearly stating initial assumptions and then deduces reasonable theorems and corollaries that can be tested in some way. Depending upon the outcome of the tests, the derived principles are modified and, if necessary, the postulate is altered. Proponents of this method feel that it provides an organized framework for conducting research. For example, a postulate could state that all stimuli present when a response is made and a drive is then reduced become capable in the future of evoking that response. Derived theorems could say that (1) all stimuli, whether noticed or not, become capable of evoking the response, (2) some response must be made in order for the stimuli to become attached to it, and (3) drive reduction is essential for stimuli to become connected to responses. Hull was the only psychologist to explicitly use this method, although it is implicitly used by many scientists in all fields.

Incentive motivation An intervening variable in the Hull/Spence system that refers to the effects of the amount and quality of the reinforcer. It was symbolized as *K*, after (Kenneth) Spence.

Independent variable Normally refers to the manipulation done by the experimenter or to some other causal event in a cause-effect sequence. If an experimenter deprives you of food or water, he or she is manipulating independent variables that will produce a change in your eating and drinking behavior. The changes in your behavior are recorded as dependent variables.

Intervening variable Term used to link the effects of several independent variables on several dependent variables. For example, suppose you are deprived of food (independent variable); the more you are deprived of food, the more you eat (dependent variable). You may attribute your behavior to hunger, an intervening variable.

Matched-dependent behavior Miller and Dollard's term for imitation. They emphasized the social importance of imitating models who are older, of higher status, or more technically sophisticated.

Molar Larger, or encompassing more. In psychology, the molar/molecular distinction concerns whether a theory deals with larger or smaller units of stimulation and behavior. A molecular theory may interpret experience in terms of discrete ideas or muscle movements, whereas a molar theory would refer to larger units. For example, molar theorists stress large units of behavior and experience extending over time, but organized according to the relevant goal involved. "Going to the store" is a molar description of behavior, where the individual movements involved would constitute a molecular description.

Molecular See *molar*.

nAch Need for achievement. A motivational construct assessed through analysis of imagery themes in written interpretations of pictures. McClelland is the best known researcher in this area.

Perin/Williams experiments Classic experiments done in the early 1940s that were used by Hull as evidence for the assumption that learning and motivation are two separate things and that learning and motivation multiply to produce performance.

Postulate A clearly stated basic assumption that guides thinking and research. See *hypothetico-deductive method* and *postulate set*.

Postulate set Set of basic assumptions from which are drawn the theorems to be tested empirically. A set of postulates reflects what the author believes to be fairly well accepted principles concerning the phenomena under study. Hull's 1943 list of postulates was as follows:

1. The afferent trace
2. Afferent neural interaction
3. Unlearned S–R connections
4. Learned habits ($_SH_R$)
5. Stimulus generalization ($_S\overline{H}_R$)
6. Drive (D) and drive stimulus S_D)
7. Excitatory reaction potential ($_SE_R$)
8. Reactive inhibition (I_R)
9. Conditioned inhibition ($_SI_R$)
10. Behavioral oscillation ($_SO_R$)
11. The reaction threshold ($_SL_R$)
12. Probability of response ($_SE_R - {_SL_R}$)
13. Latency ($_St_R$) of a response as a function of $_SE_R$
14. Resistance to extinction as a function of $_SE_R$
15. Amplitude of response as a function of $_SE_R$
16. Competing responses: the response with the greater $_SE_R$ prevails

Reactive inhibition According to Hull's eighth postulate, muscular or mental activity during learning produces an ever-increasing aversive drive, reactive inhibition (I_R). When activity ceases, this drive is reduced and a tendency to not repeat such activity results. This acts as the reinforcer that produces conditioned inhibition.

Reminiscence Improvement without practice. For Hull, this was the result of the fading of reactive inhibition. For example, when subjects are memorizing long lists of words, periods of no practice often improve performance, compared with the performance of other groups, in which the subjects continued practice without rests.

Resistance to extinction The number of responses made by a subject after reinforcement for responding is discontinued. This was used by Hull and by many other theorists as a measure of the degree of learning produced by a training procedure.

Secondary reinforcement Reinforcement produced by an event that does not reduce a biological drive. Such things as receiving praise or acquiring money are often called secondary reinforcers.

S-R psychology Psychological theories that hold that our behavior and experience may best be conceptualized as responses attached to stimuli in the world and in us. Such theories often advocate the analysis of behavior and experience into S-R associations. The original S-R theorist was Thorndike, followed by Watson, Guthrie, and many others. The most extreme S-R view was that of Hull and his many followers. Though widely criticized, this view has proven very durable and useful over the years, and a great many current psychologists believe that it is worth retaining.

Transposition Responding to relationships, rather than to absolute values of stimuli. For example, if I learn to choose a larger over a smaller circle and am then presented with the larger circle and one a bit larger than it, I show transposition if I choose the larger of the two. My behavior is controlled by the relationship of size (larger), rather than by the definite size of the specific circle. The Gestaltists stressed transposition, which posed quite a problem for Hull until Spence ingeniously proposed his theory of generalization and discrimination learning.

RECOMMENDED READINGS

Koch, S. (1954). Clark L. Hull. In W. K. Estes, S. Koch, K. MacCorquodale, P. E. Meehl, C. G. Mueller, W. N. Schoenfeld, & W. S. Verplanck, *Modern learning theory*. New York: Appleton-Century-Crofts.

This is an authoritative evaluation of Hull's theory in a volume still frequently cited. At the time it was written, Hull's theory still had great influence.

Amsel, A. & Rashotte, M. (Eds.). (1984). *Mechanisms of adaptive behavior: Clark L. Hull's theoretical papers.* New York: Columbia University Press.

This is a collection of 21 of Hull's major papers. It serves to show the continued timeliness of this influential psychologist.