Chapter 3

I. P. PAVLOV: CLASSICAL CONDITIONING

BIOGRAPHY

Ivan P. Pavlov was born in Ryazan, Russia in 1849 (see Figure 3.1). The son of a priest, Pavlov went to school at a theological seminary. He then attended Petersburg University and finally the Imperial Medical-Surgical Academy, where he received an M.D. in 1883. His work on the physiology of the digestive glands led to a Nobel Prize in 1904. Figure 3.2 shows Pavlov and some of his colleagues in his lab.

Pavlov was already well known for his work in physiology when the first translation of his "psychological" work appeared in 1927. Americans earlier had heard news of the conditioned reflex, and some had made use of it in their theoretical writings, but few at the time grasped its real significance. Even today, it is rare that Pavlov is appreciated by American psychologists. The orientation of American psychology has always been very different from Pavlov's. But his way of looking at things may have great virtues: He was not the "Pavlov" whom you may have come across in a typical psychology textbook.

Some informative publications dealing with Pavlov's theory are listed below. The last three were authored by followers of Pavlov.

Lectures on Conditioned Reflexes, 1928

Conditioned Reflexes, 1927

Selected Works, 1955

Platonov, K. *The Word as a Physiological and Therapeutic Factor*, 1959

Bykov, K.M. *The Cerebral Cortex and the Internal Organs*, 1957

Asratyan, E.A. *Conditioned Reflex and Compensatory Mechanisms*, 1965

Pavlov aimed to work out the principles that govern the workings of the cerebral cortex, the "seat of the mind." In this endeavor he used animal subjects and the conditioned reflex as the main agent of communication with the brain.

FIGURE 3.1 Ivan P. Pavlov, 1849–1936, the year that he won the Nobel Prize (1904). *From Asratyan, 1953*

Twenty years of research produced a model of brain function based on fields of excitation and inhibition. These fields bear a striking resemblance to the neural unit models, for which several researchers working in sensory physiology have won Nobel Prizes.

The influence of Pavlov in America has been restricted to the bare fact of classical conditioning; interest has been restricted largely to parametric work aimed at isolating the necessary conditions for association and the nature of the association formed. Although this has led to some interesting and useful findings, the conditioned response meant a great deal more to Pavlov than that. It was the key to unlock the secrets of the brain; it was not in itself the secret!

INTRODUCTION

Section 1 of this chapter describes Pavlov's influence as a representative of the point of view that has characterized Russian biology and medicine. This point of view has only recently received attention in Western countries. This view sees mind and body as inextricably linked, never to be treated as separate. By and large, American psychologists have not been very interested in this aspect of Pavlov's work. His influence on American psychology lies in the possibility that the conditioned reflex might prove to be the means for an objective, scientific analysis of our behavior and experience.

Although Western psychologists did not appreciate all of Pavlov's work, they were interested in classical conditioning. Section 2 presents the basics of Pavlov's theory and the phenomena of classical conditioning. It includes a brief discussion of theoretical issues that have concerned American psychologists interested in classical conditioning.

Pavlov saw his work as an extension of the work of famed English neurophysiologist Sir Charles Sherrington. A brief summary of Sherrington's analysis of the mechanisms guiding the functioning of the spinal nervous system is provided as a background for Pavlov's theory. The concept of inhibition was central to Sherrington's theory, and Pavlov spent considerable effort showing that inhibition plays a key role in the general functioning of the nervous system. His evidence has been verified largely during the past half century and is discussed in the next section.

Section 2 also describes Pavlov's model of brain function, which posits fields of excitation and inhibition interacting on the surface of the cortex. Although the model is almost certainly wrong in detail, some aspects of the model may well be correct, as suggested by important discoveries made by American researchers in sensory physiology.

Section 3 discusses criticisms of classical conditioning in general, some of which have been directed at overly enthusiastic theorists who were too quick to attempt to use the conditioned response as the explanation for everything. Criticisms of Pavlov's specific model are scarcer, since this model has attracted little notice in this country. However, the notion that fields of excitation and inhibition operate on the surface of the brain has been seriously questioned.

Section 4 considers aspects of classical conditioning that are important in everyday life. The conditioned response is beyond doubt a very important factor in child rearing, education, and advertising in ways that most of us never suspect. The effects of classical conditioning on our internal organs has been shown to be very pervasive and has many implications for what has been called *psychosomatic illness*.

1. PAVLOV'S SIGNIFICANCE IN THE EARLY TWENTIETH CENTURY

The Living Machine

"Pavlov created the body and breathed into it the mind," according to Razran (1965). It will be easier to understand what Razran meant by such praise after reading this chapter. Recall that the thinkers of the past several centuries had passed on the legacy of Descartes, a legacy that lives on in our commonsense views concerning the mind. According to this view, which is really the only one we are taught, it is obvious that we each have (or are) a mind trapped in the physical structure of a body. We view the body as a marvelous machine that carries out all sorts of complicated functions, only some of which we understand. It is indeed marvelous, but it is still a machine. (Science fiction writers have little difficulty convincing us that it is possible that "I"—my mind—could be transferred into a different body, either by a mad genius or as the result of a breakthrough in medical science.)

Pavlov's views, and those of his colleagues, were quite different. For them, the body is also a machine and it is also marvelous, but it is a *living* machine. A body made up of living parts does not require a separate mind to guide it; there is mind, of course, but it is seen as the product of the workings of a living body, not as a separate entity. This is similar to Aristotle's view, and it implies, among other things, that there is no specific ailment that could be called psychosomatic. Psychological and biological factors are inseparable, so any disease is thus psychosomatic. Can any biological malfunction fail to influence the psyche? Can psychic disturbances fail to influence the body?

The relative contribution of psyche and soma to individual ailments may vary, of course, but it is never the case that mind and body act independently so that only *one* is involved. Concerning psychotherapy, Platonov (1959) refers to this difference in Russian and American points of view: "Soviet psychotherapy has developed under conditions entirely different from those in foreign countries and in pre-revolutionary Russia. It is being built on the basis of dialectical materialism, a materialist teaching of the higher nervous activity, the unity of the mind and body, and the determination of consciousness by the conditions of life" (1959, p. 11). Regarding bodily illness, Platonov wrote: " . . . In light of the theory of the unity of mind and body any somatic disease is indissolubly connected with the state of the patient's higher nervous activity" (1959, p. 12).

Given a mechanical (living) body and its product (the mind), how does one understand its workings? Pavlov believed that this was the business of physiology and that the psyche was best studied through the investigation of the physiological activity of the cerebrum. Pavlov's work showed how the adjustments we make as the conditions of the world change around us can be understood as the workings of an integrative mechanism, controlled largely by the cerebral cortex. (This work will be described later in the chapter.) The significance of Pavlov's work was

TABLE 3.1 Classical Conditioning of Food-Anticipation Behavior

Conditioned Stimuli	*Unconditioned Stimuli*
Smell of food Taste of food Food dish Attendant	Food in mouth or stomach innate reflex
learned reflex (conditioned response)	*Unconditioned Response*
	Salivation Agitation Licking lips Thoughts of food

of our behavior and experience as the accumulation of conditioned reflexes. If we make such an assumption and leave it at that, however, we part company with Pavlov.

The CR in America

Early American psychologists did propose such a possibility. Given that we are born with a set of reflex behaviors, each elicited by specific (unconditioned) stimuli, is it not reasonable that pairing these behaviors with reliable cues establishes the cues as conditioned stimuli? Then, with new reactions to a host of stimuli, our behavior and experience amount simply to compounds and sequences of reactions to conditioned stimuli. This obviously includes experience, since the conditioned response to food includes the thought of food and of the pleasures of eating!

American researchers and theorists adopted the terms used by Pavlov (these will be discussed below) and concentrated on the specific conditions that produce Pavlovian conditioning, or *classical conditioning*. For example, Pavlov suggested that the conditioned response develops faster if the cue slightly precedes the unconditioned stimulus (by a second or so) but that it still occurs if far longer delays are used. But what is precisely the best delay between conditioned and unconditioned stimuli? Such information could tell us something about the minimum time required for neural transmission and thus give us clues about the nervous mechanism involved in the formation of a single association. Pavlov showed little concern with such problems, whereas Americans have shown a great deal of concern. This does not necessarily mean that either Pavlov or American researchers were mistaken. It merely emphasizes a basic difference in point of view.

American researchers have concentrated on similar details of the conditioning process, such as the effect of the strength of the conditioned and unconditioned stimuli, the effects of motivation, the effects of drugs, and so on. Such research continues today, in the hope that once we understand the details of the classical conditioning process, we will understand the basic mechanism of association. In fact, this research has led to developments of new theories as well as to some discoveries of practical importance, as we will see in Chapter 9. But such a strategy was not what Pavlov had in mind.

Pavlov's emphasis of the conditioned response as a tool for the study of brain function never caught on in America. Nor did his model of brain function. His irritation with those who failed to appreciate the integrative activity of the organism was plainly evident in his attacks on them (e.g., Pavlov, 1932). Razran (1965) details the objections that Pavlov and his many followers have raised against the American conception of conditioning.

American psychologists saw Pavlov's discovery as fundamentally important. Their reasons were different from those that guided Pavlov. They sought a unit into which to analyze behavior, whereas Pavlov sought a method for studying brain functioning.

Summary

Pavlov viewed humans as living machines, rather than as nonliving robots guided by a separate

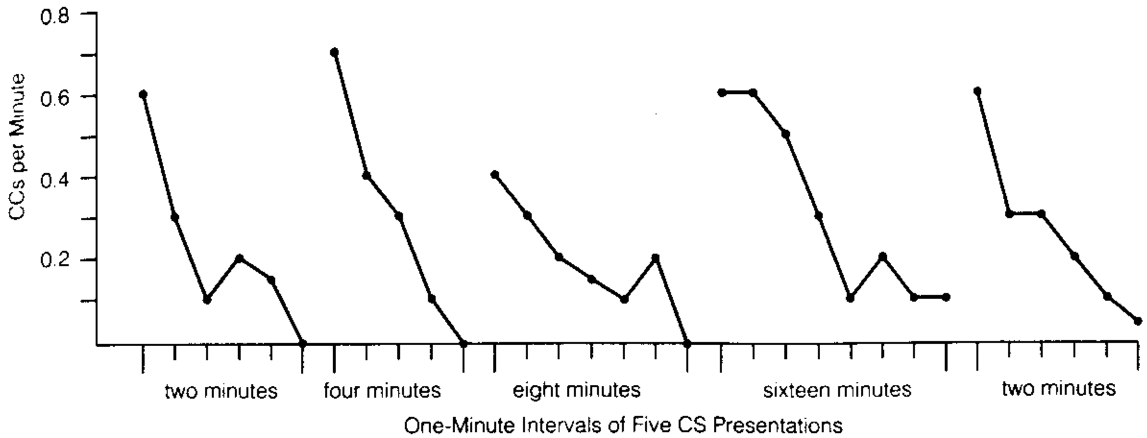

FIGURE 3.3 Extinction with different CS presentation intervals (Pavlov, 1927, p.52).

conditioned eyelid [nictitating membrane] response in rabbits.)

Another popular method for studying classical conditioning is the study of *conditioned suppression.* In this procedure, a CS is paired with an aversive UCS, such as electric shock. Soon a CR appears, which may be indicated by the flinching or the "freezing" of the subject. To more precisely assess the strength of this fear response produced by the CS, it is then presented while the subject is occupied in some other activity, such as pressing a panel for food.

If panel pressing is diminished during the CS, we may conclude that the CS has become aversive and that the decrease in pressing is due to fear-produced suppression. In practice, the degree of suppression is often assessed by calculating a *suppression ratio*, comparing responding just prior to the CS (A) with responding during the CS (B). This ratio, $\frac{B}{A + B}$ would be 0.5 if no suppression occurred and would decrease toward zero as the degree of suppression increased (and as responding thus decreased during the CS).

Excitatory and Inhibitory Conditioning A CS that more or less reliably predicts a UCS is termed an excitatory CS; it is effective in producing a CR. A CS that more or less reliably predicts ***no*** UCS is termed an inhibitory CS; it does not produce a CR. According to some theories, such as Pavlov's and Konorski's (1948), an inhibitory CS may actually produce a response opposite to the CR (see below). Note that *excitatory* and *inhibitory* refer to the predictive character of the CS, not to whether what is predicted is good or bad. Thus, an excitatory CS may predict food or strong shock.

Generalization and Discrimination Once a CS has been established, we find that similar stimuli may also produce a CR, with the magnitude of the CR depending upon the similarity of the new stimulus to the CS. This spread of excitation or inhibition is called *irradiation*. Pavlov referred to the irradiation of excitation (and inhibition) from the cortical spot representing the CS to spots representing similar stimuli. We term the effect stimulus generalization. Figure 3.4 shows the results of a dog's responding to tactile stimulation on the skin. Stimulation of the thigh had been paired with food and was thus a positive CS (CS+). The salivation CR decreased as more distant surfaces of the body were stimulated.

If a new stimulus is presented occasionally with no UCS, and our CS is presented at other

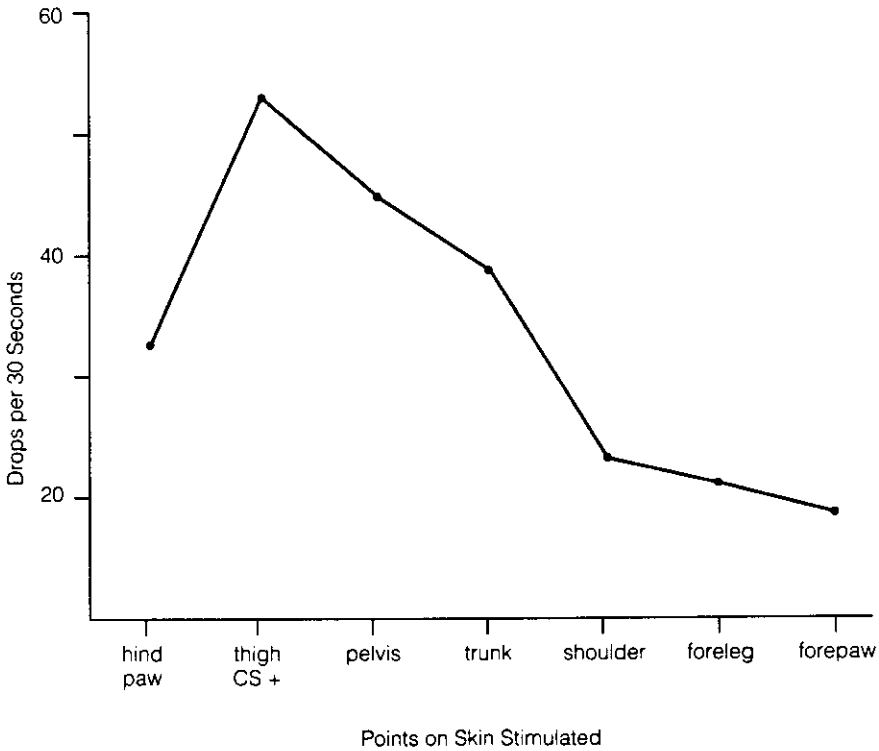

FIGURE 3.4 Irradiation (Pavlov, 1927, p. 185).

times with a UCS, the generalized responding to the new stimulus gradually fades. Pavlov referred to this as the formation of a *differentiation* and we usually term it discrimination learning. The study of the formation of discriminations constitutes a large part of Pavlov's research.

The UCS An unconditioned stimulus may be food, electric shock, an air puff to the eye, brain stimulation, the sight of a rival, a loud noise, a morphine injection, the caffeine in a cup of coffee, and so on. It is effective if it evokes a reasonably strong bodily response.

Unconditioned stimuli are typically classified as *appetitive* or *aversive*, roughly corresponding to whether we typically view them as pleasant or as unpleasant. We will see later that some powerful UCSs such as stimulation of the stomach or intestines are difficult to classify in this way.

A CR is generally produced more easily when the UCS is more intense. Needless to say, there are limits to this, and it should be remembered that the CR is usually similar to whatever the UCR is. Suppose you are trying to produce an eye blink response and the UCS is intense enough to blow the subject off the chair; such a UCS probably will not lead to a stronger CR.

The CS Almost everything imaginable has been or could be used as a CS. Pavlov was fond of using spinning disks, the sound of bubbling water, and a metronome as conditioned stimuli. Recently we have found that some stimuli act particularly well as signals for certain UCSs. For

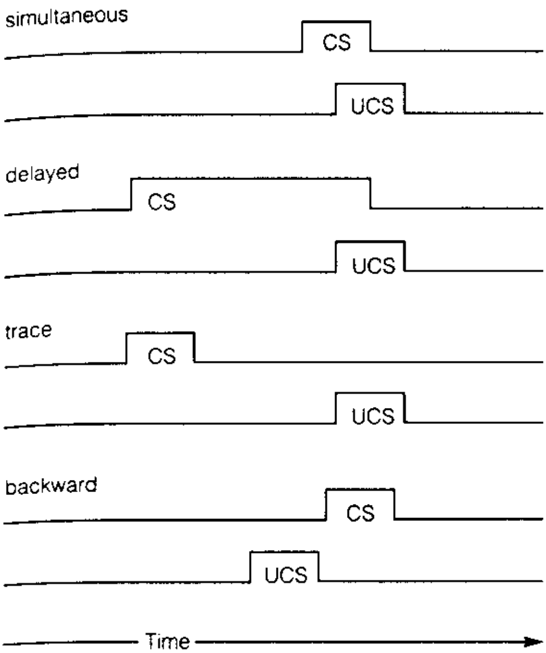

FIGURE 3.5 Temporal paradigms of conditioning. This figure shows the ways in which a CS and a UCS may be presented in time. For example, delayed conditioning occurs when a CS is presented and remains present over seconds or minutes and the UCS appears at the end of the CS presentation. In trace conditioning, the CS is presented and removed, a period of time passes, and the UCS then appears.

example, tastes are established very quickly as CSs for poison-produced illness (see Chapter 9).

The intensity or general salience of a stimulus is important in establishing it as a CS. Pavlov found that, if two stimuli are presented together, the more salient one could overshadow a less salient stimulus, leaving the latter one ineffective (1927). We will return to this topic in Chapter 9.

The Temporal Paradigms Pavlovian conditioning works best when the CS precedes the UCS by a second or so, which Pavlov called *simultaneous conditioning* (see Figure 3.5). He did not actually present the CS and UCS simultaneously, since he believed that this would render the CS useless as a signal and thus that conditioning would not occur. (In the U.S., the meaning of *simultaneous* is taken literally. To researchers in the U.S., *simultaneous conditioning* means that the CS and the UCS occur at exactly the same time.)

A good deal of research supports Pavlov, but some recent investigators, such as Heth (1976), have found that conditioning may occur when the CS does not precede the UCS. If the stimuli appear simultaneously (and even when the UCS begins shortly before the CS), the CS may become weakly effective. With continued training it may then become inhibitory, as Pavlov found.

If the CS is presented and remains present, with the UCS occurring seconds or minutes later, we have *delayed conditioning*. Pavlov typically began with the CS and UCS closely paired in time and gradually increased the delay between the onset of the CS and that of the UCS. (American researchers typically do not do this.) Thus, a tone would begin to sound and the interval between its onset and the presentation of food might be extended to ten or fifteen minutes or more. Eventually the salivary CR did not begin with the onset of the tone; after one third to one half of the delay period passed, salivation began and continued at an increasing rate until the food was presented. This pattern may appear only after fairly lengthy training, but Pavlov's experiments frequently extended over weeks or months, and he often used the same subjects over years of research.

Pavlov believed that the decrease in responding during the initial part of the delay period was due to the building up of inhibition in the dog's brain. The early part of the period was never paired with the UCS and thus became an inhibitory CS. He further believed that inhibition leads to hypnosis and sleep, and he saw evidence for this in the behavior of many of his dogs. He found that many animals fell asleep, often snoring loudly, during delayed conditioning; even an initially frisky and active dog would quickly doze

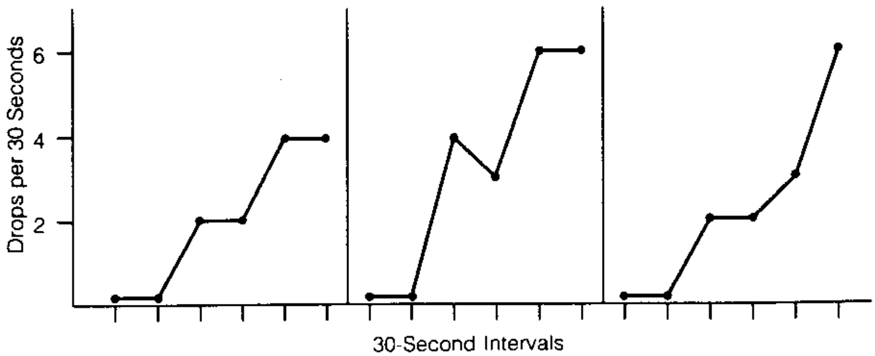

FIGURE 3.6 Results from a delayed conditioning procedure (Pavlov, 1927, p. 90). This figure shows three instances of responding during delayed conditioning. A CS+ (whistle) was presented for three-minute periods, followed by a UCS (weak acid, producing a sour taste). Data points represent salivation during successive 30-second periods within each three-minute presentation of the CS.

off once a session of delayed conditioning began. He referred often to the time and effort he and his assistants spent in rousing the drowsy canines (Pavlov, 1927).

Since conditioning occurs most rapidly when the CS precedes the UCS slightly, it may be of interest to determine the best interval between CS and UCS. It has been pretty well established (e.g., Mackintosh, 1974) that an interval of approximately half a second is best when the UCR is a phasic response, such as the flexing of a limb or the blinking of an eye. If the response is less phasic, such as salivation or a change in the heart rate, a CS–UCS interval of five to ten seconds seems best. (Chapter 9 discusses studies in which the CS–UCS interval spans hours.) Figure 3.6 presents the results from a delayed conditioning experiment.

If a CS is presented, turned off, and later followed by the UCS, the procedure is called *trace conditioning*. Note that it is identical to delayed conditioning, except that the CS ends before the UCS appears. Pavlov called this procedure trace conditioning because he assumed that a CR to the now absent CS was actually connected to a memory trace of the CS. The pattern of responding in trace conditioning is similar to that in delay conditioning; after some training, the CR begins to occur after one third to one half of the CS–UCS interval has passed and continues increasing in magnitude up to the delivery of the UCS.

Backward conditioning involves the presentation of the UCS before the presentation of a CS signal. It is fairly well established that conditioning does occur under such conditions and that the CS is rendered inhibitory; it signals "no UCS." Researchers Keith-Lucas and Guttman (1975), among others, found that backward conditioning can produce a normal excitatory CS. Other researchers, such as Heth (1976), found that the CS may become mildly excitatory early in training. But typically, given enough training, backward conditioning renders the CS inhibitory. For example, Moscovitch and Lolordo (1968) showed that backward conditioning with an electric shock UCS makes the CS an effective fear reducer.

Controls in Classical Conditioning Control procedures are used to ensure that any CRs that occur are due to the pairing of some CS with some UCS and not to other factors. At least, that used to be the purpose of controls. Things have changed, as we will see. Suppose we begin with a CS that reflexively elicits a UCR. In eye blink conditioning, for example, a bright light CS may produce a blink before an air puff ever occurs. The odor of vinegar produces salivation and thus would be an unwise choice for a CS in salivary conditioning, although it would be fine as a UCS.

Sensitization or pseudoconditioning occur when a CS produces a response that looks like a CR without any pairing with a UCS. For example, if one is using an air puff UCS to produce an eye blink UCR, a bright flash of light or a clap of thunder would be unwise choices for a CS. Either could produce a startle response (eye blinks) that could be mistaken as CRs arising from the CS–UCS pairing. *Pseudoconditioning* occurs when the CS evokes a response because the UCS (such as electric shock) has rendered the subject overly reactive to stimuli in general.

The purpose of control procedures is to ensure that whatever CR occurs is due to the classical conditioning procedure and not to some other factor. In the past, classical conditioning was viewed as the simple pairing of CS and UCS, and the experimenter controlled against the effects of other variables. That changed in 1967 when Rescorla published a paper entitled "Pavlovian Conditioning and Its Proper Control Procedures." He proposed a *truly random control* procedure, in which CSs and UCSs are presented at random times. Although the CS and UCS may occasionally be paired accidentally, no CRs develop. That is because the CS is also likely to be followed by no UCS and thus provides no information about the possible occurrence of a UCS. In order for learning to occur, the CS must reliably signal the UCS. (We will return to this subject in Chapter 9.) In any event, if the CS you use reflexively elicits UCRs, or if the UCS sensitizes the subject so that CRs seem to occur, you will observe what seem to be CRs even using the truly random control procedure. You would thus know that these factors could produce spurious apparent CRs in your experimental groups.

Traditional Theoretical Problems, Briefly

What Is Learned in Classical Conditioning? Pavlov believed that the appearance of a CR meant that the CS had become a substitute for the UCS. For example, when a light is paired with food, a connection forms between the cortical centers representing the light and the food. Once this occurs, the sight of the light activates the CS (light) center, which is now linked with the UCS (food) center and thus a food reaction CR occurs. What has been learned is an association between two stimuli, the light and the food. This is called a stimulus-stimulus, or S-S, association. Pavlov provided evidence for this interpretation: In experiments in which a light was paired with food, Pavlov found that his subjects often licked the light if they could, thus showing that they treated them as they did food.

Sensory preconditioning is a phenomenon that seems to support the notion that classical conditioning is S-S learning, although in fact it simply shows that such associations do occur in common experience (e.g., Razran, 1961). If we present two stimuli, such as a light and a tone, repeatedly (light-tone, light-tone, and so on), there is evidence that an association is formed even though we have applied nothing that could really be called a UCS. This may be shown by later pairing the tone with a real UCS, such as electric shock. This leads to the formation of a CR (the subject's flinch, heart rate change, and so on) to the tone.

If we then present the light, a CR (perhaps a weak one) is also produced, even though the light has never been paired with the shock. This means that the previous pairing of the two stimuli (light and tone) was enough to associate them even in the absence of an obvious response to either of them. Classical conditioning involves the pairing of stimuli and thus probably involves S-S learning.

But there is also evidence that classical conditioning is S-R learning, a view more compatible with American learning theory during this century. Returning to the pairing of a CS and food, it could be that the salivary CR to the CS occurs because that was part of the response last made when the CS was present. Food (the UCS) was also present, and salivation occurred. What was learned was an association between the CS and the last response made to it (R); hence, an S-R association was learned. An early experiment by Harry Harlow, which involved changing the effectiveness of a UCS after pairing it with a CS, provided evidence for an S-R association.

Harlow (1937) used a UCS consisting of the loud noise produced by the popping of a paper bag previously blown up by his graduate student aides. Each bag pop was preceded by a brief buzzer CS, and this CS soon produced CRs of agitation and fear in his chimpanzee subjects. After the CR was established, Harlow repeatedly presented the UCS (bag pop), especially while the chimps were eating. Eventually, the noise lost its earlier effect; the chimps became accustomed to the noise (they habituated) and no startle UCR appeared. How did the habituated chimps respond, then, to the sound of the buzzer? (The buzzer was still a signal for the bag pop, but the pop no longer produced a fear response.) If classical conditioning is, as Pavlov and the previous argument suggests, S-S learning, then the buzzer should have no effect. (It signals a UCS that now has no effect.) But the buzzer did have an effect: The chimpanzees jumped with fright. Why?

Evidently, the buzzer produced fear not because it signaled the impending noise of the bag pop. It produced fear because that was what it produced the last time it was present. The association formed then was between the CS (buzzer) and the UCS (fear). Thus, classical conditioning, as Harlow's experiment shows, is S-R learning.

Is classical conditioning S-S learning? Is it S-R learning? Is it both or neither? Have researchers miscast the problem or the evidence? Are they asking inappropriate questions? We could consider other evidence for both sides and the reader should not be left with the impression that this is an easily resolved issue.

Rescorla (1973) was unable to replicate Harlow's finding, and later research suggested that if it is reasonable to treat classical conditioning as S-S or S-R learning, the ordinary (first-order) conditioning seems largely to be S-S learning. However, second-order conditioning seems largely to be S-R learning (e.g., Konorski, 1948; Rizley & Rescorla, 1972).

Konorski (1948) paired a CS (call it CSa) with food, producing conditioned salivation in his dog subjects. He then paired a second CS (CSb) with CSa. Then CSa was paired with shock, producing a conditioned leg flexion response. But presentation of CSb still produced salivation. Table 3.2 shows this situation.

Holland and Rescorla (1975) sated their rat subjects with food after establishing a light as a first-order CS for food and a tone as a second-order CS. They found that the response to the light was greatly reduced; it was, after all, a signal for food, and food is not an effective CS for a sated subject. The conditioning involved was S-S learning. But when the tone was presented, its effect was not diminished. Although the tone was a signal for the light and the light was a signal for food, the tone was still effective even when the light was not. This must mean that second-order conditioning is not S-S learning; rather, it is S-R learning. (This would explain why the tone was effective even when the light was not.) When the tone was last presented, it produced a response (the CR), and that was what it produced subsequently. If it merely signaled the light (and thus the food), one would expect no response from a sated subject, as was the case with the light.

The picture clouds a bit when we consider several responses. Holland (1977) found, perhaps surprisingly, that different CSs evoke different reactions even when the same US is used. He paired a variety of stimuli with food and then tested the response to each stimulus. The experiment showed that a tone CS elicited strong head jerking and that a light CS did not. But the light elicited rearing, whereas the tone did not. These examples make one suspect that S-R learning is involved; the form of the CR is specific to the type of CS. However, if we look at second-order conditioning, in which other stimuli signal light or tone, no such difference occurs. Is the learning in this case S-S learning?

First- and second-order conditioning may reflect S-S and S-R learning, respectively, if one records standard single CRs, such as suppressed bar pressing, during a CS signaling shock. If one

TABLE 3.2 Three Experiments: S-S Learning or S-R Learning?

Sensory Preconditioning	
Procedure	*Assumed Process*
1. pair light and tone	S_1-S_2 (light-tone) association
2. pair tone and shock	S_1-S_3 (tone-shock) association
3. present light: shock CR	S_1-(S_2)-S_3 association
Changed Effectiveness of the UCS	
Procedure	*Assumed Process*
1. pair buzzer and noise	S-R (buzzer-fear) association
2. habituate noise UCR	noise ineffective UCS
3. present buzzer: fear CR	S-R (buzzer-fear) association intact
Second-Order Conditioning	
Procedure	*Assumed Process*
1. pair CSa and food	S-S association
2. pair CSb and CSa	S-S association
3. pair CSa and shock to leg	S-S association
4. present CSa: leg flexion CR	S-S (CSa-shock) association
present CSb: salivation	S-R (CSb-salivation) association

observes several kinds of responses, first- and second-order conditioning seem to involve S-R and S-S learning, respectively. In short, the results are confusing and inconclusive.

Reinforcement in Classical Conditioning This problem is actually difficult to separate from the problem of what is learned. The problem concerns the effect of the UCS: Does the UCS act as a reward for whatever CR appears? Or is the UCS strictly an elicitor, which produces a strong CR by producing a strong UCR? This seems at first glance an opaque question, not easily answered. But the evidence clearly shows that the UCS does not work primarily like a reward. If it did, this would mean that the UCS would act like a satisfier, as Thorndike used the term. It would also mean that classical conditioning would simply be a case of *instrumental conditioning*, or learning that depends on the consequences of responses.

Consider some examples: In salivary conditioning, dry food is ordinarily administered to the mouth; Pavlov used dry meat powder. The CR of salivation that occurs surely makes the dry powder more palatable, so the behavior of salivating is thereby rewarded. Not salivating is punished by the discomfort of a mouthful of powder. Similarly, eye blink CRs are rewarded; an anticipatory blink avoids an annoying puff of air to the eye. In normal eyelid conditioning, the consequences of the CR probably maintain the CR. This essentially was Hull's position (see Chapter 6); his theories dominated psychology for many years.

Unlike the problem of "what is learned," the evidence seems to be quite clear in this case. Conditioned responses are not maintained by their consequences. This has been shown in a variety of studies using what Sheffield (1965) calls *omission procedures*. For example, suppose we reward a dog with food for *not* salivating. Given no salivation, we present food. If there is salivation, the food reward is omitted. If the salivation response is maintained by consequences, the omission of food which follows salivation should lead to decreased salivating, and the food presented for not salivating should likewise reduce salivating. But if salivating is determined solely by the UCR produced by the UCS food, it should be impossible for the dog to learn to withhold salivating when the reward is food. And, of course, Sheffield found that it was impossible to train dogs to withhold salivating when the reward was food.

A variety of other data with omission schedules has almost always supported this finding and clearly show that the UCS in classical conditioning does not act like rewards in instrumental learning. Does this mean that classical conditioning and instrumental conditioning are fundamentally different?

Classical and Instrumental Conditioning The procedures used in classical conditioning and instrumental learning are different; some theorists have suggested that there also is a fundamental difference in the kind of learning that takes place. First, let us consider how similar are the procedures involved.

In classical conditioning, a CS, such as a light, is presented just before a UCS, such as food, which produces a UCR (eating and so on). After the CR to the light is established, the sequence of events is typically as follows:

$$CS \rightarrow CR \rightarrow UCS \rightarrow UCR$$

In instrumental learning, we may reward a response with food in the presence of a (discriminative) stimulus light. Thus, the sequence:

$$\text{light} \rightarrow R \rightarrow UCS \rightarrow UCR$$

The only real difference lies in the fact that the CR in the first sequence is elicited by the UCS. In the second sequence the response may be anything we choose (although we will see that a lot of responses that are chosen arbitrarily, such as bar pressing and key pecking, seem to act a lot like CRs). There is still a difference in procedure, of course between classical and instrumental conditioning; this has been emphasized by Catania (1984) and others. In classical conditioning, the UCS occurs independently of the behavior of the subject, whereas in instrumental conditioning the consequences depend on the occurrence of some aspect of behavior.

Earlier psychologists did not distinguish between two kinds of learning. The possibility that Pavlovian and instrumental learning were fundamentally different was suggested by Konorski and Miller (1937), but the real argument for the distinction was made by Skinner in 1938. He suggested that instrumental (or operant) learning is dependent upon the consequences of action (rewards or reinforcers), that it applies only to the skeletal nervous system and the striped muscles which it controls. According to Skinner, classical conditioning (or respondent learning) affects only the autonomic nervous system and the smooth muscles of the viscera and glands controlled by the autonomic nervous system. He also distinguished the two types of learning in other ways, as we will see in Chapter 8.

Some psychologists, such as Mowrer (1947), adopted Skinner's distinction, but many did not. Nonetheless, the distinction between classical and instrumental conditioning has been accepted by a great many psychologists over the past half century. For this reason, there has been a great deal of interest in demonstrations of the instrumental conditioning of autonomic behavior, largely by Neal Miller and his associates (e.g., Miller, 1969). Miller has shown that it is possible to influence heart rate, blood pressure, and other autonomically controlled responses with feedback (that is, providing consequences). Some researchers have questioned Miller's results. In addition, Miller and others have failed to replicate his original findings (e.g., Miller & Dworkin, 1974; Dworkin & Miller, 1986). However, there is little doubt that instrumental conditioning, as a procedure, can influence a variety of bodily activities (cf. Buck, 1988). *How* this occurs, though, is very much a matter of debate.

Researchers also have shown that what was thought to be instrumental behavior, such as the pecking of a plastic disk by pigeons, may be established by what seems to be classical conditioning procedures. For example, Brown and Jenkins (1968) showed that one need only present a lighted key for a few seconds, followed by the automatic delivery of food, to establish key pecking in pigeons. Reliable responding almost always occurs after less than 100 pairings. The lighted key seems to act as a CS, and the birds' pecking, which seems a reasonable CR when the UCR is pecking grain, occurs to the lighted key.

These studies, and other research conducted during the 1970s and 1980s, has blurred the distinction between classical and instrumental learning. If visceral behaviors can be influenced by feedback procedures (instrumental conditioning), and if classical conditioning procedures can influence skeletal behavior, such as key pecking, then the distinction between the two procedures surely does not extend to some basic difference in the two main divisions of the nervous system (autonomic and skeletal) involved. Today, the distinction between classical and instrumental learning is far less popular than it was in the 1960s.

Sherrington's Integrative Action

Pavlov was concerned with the way in which the brain functions, assuming that this was the key to understanding behavior and experience. His work during the beginning of this century, which included the "discovery" of the conditioned reflex, was inspired by the then recent work of the great English physiologist Sir Charles Sherrington. To understand Pavlov's theory, it is necessary to know a little about Sherrington's work.

Sherrington was to win the Nobel Prize in 1932 for his earlier work, published in 1906, concerning the workings of the spinal nervous system. His book, *The Integrative Action of the Nervous System*, had two major effects. First, it established the reflex as the basic unit of spinal physiology by showing what effects the synapse has on neural activity. (The synapse is the tiny gap between the axon of one neuron and the cell body of another, so named by Sherrington.) Secondly, Sherrington showed how the spinal cord acts as an organ of integration, coordinating the activities of individual organs. This action, which he called *integrative action*, cannot be understood by a concentration on individual reflexes or collections of them. For example, often stimuli are present that would lead to incompatible actions; a touch on the skin may provoke receptors that produce both flexion and extension of a limb. For a while, there is competition between the two antagonistic movements. Unless the limb is to remain stiff, one of the receptor groups temporarily "wins." For example, receptors and their afferent (sensory) arcs, producing flexion of the biceps, also produce flexing of the arm. While the limb is flexed, the muscle producing the antagonistic movement (the triceps muscle) is inhibited. Thus, one effect—the flexing of the arm—involves the contraction of one muscle group and the *reciprocal inhibition* of the antagonist.

This is only a brief sketch of Sherrington's integrative action; it becomes very complex when we consider all of our spinal sensory nerves competing for the limited number of motor nerves (Sherrington's *final common path*) controlling all of our many skeletal muscles. The little processes happen at many levels with every movement that we make, whether it be typing, lifting a coffee cup, swinging a bat, or simply running. According to Sherrington, individual reflexes or their simple sum tell us little.

These mechanical principles of integration apply only to the action of the spinal cord, in Sherrington's opinion. The cerebral hemispheres do not act according to such mechanical principles. Sherrington really was at bottom a mentalist who firmly believed that some sort of spiritual entity—a separate mind, or the like—governed the activity of the brain, as he makes clear in the final chapters of his 1906 book. Nonetheless, it was Pavlov's aim to show that such mechanical principles did apply to the workings of the brain, and he bitterly attacked Sherrington's refusal to consider the possibility (Pavlov, 1955).

Pavlov tried to apply Sherrington's basic approach to the study of the cerebral cortex. And, like Sherrington, he based his conclusions on inferences drawn from behavior, rather than from direct measurements of the activity of the nervous system.

Pavlov's Evidence for Inhibition

Pavlov believed that *inhibition* was as important in the functioning of the cerebrum and thus in the overall function of the individual as Sherrington had shown it to be in the activity of the spinal cord. The usefulness of the concept of inhibition in behavior has been hotly debated during this century, with some theorists accepting it and others (notably B. F. Skinner) arguing strongly against it. The basis for the debate is easy to see if we consider a concrete example in classical conditioning.

Imagine a hungry dog that is occasionally fed a small morsel of food. Just before each piece of food is given, a green light in front of the dog comes on and remains lighted while the food is delivered by an attendant. At other times a tone is briefly sounded and no food is delivered. When neither the light nor the tone is on, no food is presented. Before long, the repeated presentations of the light and the food have their effect; the dog appears to anticipate food when the light comes on, as is evidenced by the dog's salivation and bodily movements. During the tone and during periods with no light or tone, nothing happens; the dog doesn't salivate but appears to be waiting for the light.

During these periods of no response, it seems sufficient to say that there is simply no tendency to respond. The absence of responding does not mean that inhibition is involved. Inhibition would mean that, not only is there no tendency to salivate (and so on), but that such behavior is actually suppressed.

Then conditions change. When the light comes on, the dog is still given food, but now it is given food on one occasion in which neither the light nor the tone is on. Needless to say, the dog accepts and eats the food. Then the light and food are presented, followed by the tone. This time, however, food is presented during the tone. Does the dog accept and eat the food? Surprisingly, it does not! Instead, it turns away; if the food is forced on the dog, it refuses it! The green light comes on, food is offered, and the dog eats it.

The reason for this seemingly bizarre behavior lies in the conditioned response established in the no light/tone periods and in the tone periods. Just as the light produces an excitatory conditioned response (CR) to the food, the tone becomes inhibitory. As a reliable predictor of "no food," it evokes an "antifood" response—a lack of readiness for food, as defined in terms of Thorndike's conduction units. The no light/no tone periods produce no such effect; due to long experience both with and without food in the no light/tone conditions, such periods predict nothing. The tone, however, has come to mean "no food" and has thus become an inhibitory stimulus for eating.

This observation, reported by Konorski (1967, pp. 325–326), is shown in Table 3.3. It is likely that such effects are common in our experience and behavior, despite the fact that inhibition has often been argued to be unnecessary. After all, the absence of an activity does not have to mean that it is inhibited (that is, that the tendency to do it is less than zero). The tendency, if it exists at all, could simply be too low (near zero) to lead to action. Yet, the tendency to eat during the tone was not simply low, as during the no light/tone periods; during these times, food was refused. It would take more trials than usual to establish a CR to the tone. This deficit in reconditioning shows that the CS was indeed inhibitory.

Pavlov's evidence for inhibition was less startling and was integrated into his presentation of

TABLE 3.3 Konorski's Simple Demonstration of Inhibition

CS+	*Intertrial Interval*	*CS−*
Tone paired with food	No food given	No food given
Dog eats free food	Dog eats free food	Dog refuses free food

the basic features of classical conditioning. The following summary presents this evidence, along with a further discussion of some of the basics of conditioning. For simplicity, we will consider the classic case of salivary conditioning, in which a CS tone precedes a UCS of food in the mouth and a CR including salivation appears when the tone is sounded.

As the tone and the food are presented repeatedly, salivation more reliably accompanies the onset of the tone and the rate of salivation increases. Pavlov viewed this as evidence for a connection formed in the brain centers corresponding to the tone and the food in such a way that the tone becomes a substitute for the food. With repeated pairings, the connection becomes stronger, as excitation from the cortical "eating center" drains to the center representing the tone. As conditioning proceeds, the tone becomes a more excitatory CS.

Extinction If the food UCS is no longer presented and the tone CS appears alone, the reliability and vigor of the salivation CR to the tone decreases until eventually the tone produces no CR; the CR has been extinguished. During this period of extinction, the decrease in the rate of salivation is not smooth but irregular. There may be salivation with one presentation of the tone, none during the next, salivation with the next, and so on. This ragged course of extinction was evidence to Pavlov that conflict was present. The excitatory CS was becoming inhibitory and the irregular rate of decline of the CR was evidence for an excitatory/inhibitory conflict. This is not altogether convincing evidence for the existence of inhibition (cf. Rescorla, 1969), but Pavlov had other forms of evidence that seem more convincing.

For example, consider the effect of repeated presentations of the tone. Imagine that the subject is a dog (although it need not be) in a standing position in a restraining harness. The tone has been presented a number of times without food, and the dog shows no response to its presentation: No salivation occurs, and the dog does not turn its head toward the source of the tone. The tone continues to be presented again and again at intervals. The dog goes to sleep, often snoring loudly, according to Pavlov's account. The dog occasionally awakens, shows no reaction to the tone, and falls asleep again. The procedure continues and something odd happens.

While awake, the dog beings to act strangely; its muscles relax and it appears to be in a hypnotic state. This is not simply due to boredom, as one might suspect, because, when we look more closely, we see that strange things are happening. If other conditioned stimuli, which earlier had been paired with food, are presented, the dog may not respond to them or to food itself. Oddly, if the dog does react to conditioned stimuli, it responds more strongly to weak stimuli than to strong ones. Pavlov called this the *paradoxical phase* of extinction. In Pavlov's experiments, a weak light CS produced a stronger reaction than a shrill whistle, both of which were paired with food equally in the past.

As the tone continues to be presented in extinction, the *equalization phase* appears. While awake, the dog responds with equal vigor to presentations of weak and strong conditioned stimuli. Finally, this stage gives way to the *ultraparadoxical phase*, in which positive CSs produce no responses but negative CSs produce CRs. In Pavlov's experiments, the dog responded to the tone (the negative CS) but not to the conditioned stimuli that signaled food (the positive CSs).

Pavlov felt that these stages were due to the building up of inhibition produced by presentations of the tone without the food UCS and that this build-up upset the normal balance of excitation and inhibition in the brain. This inhibition also produced sleep, even in rested and alert subjects. Pavlov and his assistants spent a good deal of time keeping the dogs awake. He mentions wearing scary masks and blowing toy trumpets for just this purpose.

The dog's behavior as it passed through these stages often seemed insane and was interpreted as indicating a form of neurosis, called *experimental neurosis*. Interestingly, a fine analysis of the stages through which the dogs passed, as shown in their behavior, corresponds closely to a categorization of stages of mental illness in humans (e.g., Platonov, 1959). For many years the Russians have viewed mental disturbance as the product of excitatory and inhibitory factors, following Pavlov's interpretation. Eysenck (e.g., 1957) favors this general point of view, but other Western psychologists have ignored it, as Razran (1967) noted. Attempts by Americans to duplicate the stages of "sleep" described by Pavlov and by Platonov, and by others (e.g., Frolov, 1937), are rare, if they exist at all.

Pavlov believed that experimental neurosis resulted from a conflict between excitation and inhibition and occurred when an impossible problem is posed. For example, one may pair a circle with food presentations and alternate presentations of an ellipse that appears without food. The discrimination begins with the two stimuli appearing quite different, and the subject quickly comes to salivate only during the presentations of the circle. Gradually, the stimuli are made more similar (the ellipse is made more nearly circular), until the subject no longer can distinguish between the two shapes. This should not cause any panic in the subject; in fact, a half comatose subject could just let its salivary glands work or not. Food comes with the CS+ no matter what the dog does, and food does not come with the CS− no matter what the dog does.

Although there should be no ill effect, there is one. When the task becomes nearly impossible, the dog becomes agitated, barks, salivates, bites at its harness, and generally goes berserk. To prevent injury, the dog is removed and placed back in the kennel, where it may remain "insane" for months or years. (It is tempting to suppose that similar hazards may conceivably attend familiar methods of education such as a programmed learning task in which steps of successive difficulty are arranged so that a mistake is never made because the successive steps are carefully arranged to prevent it. What if a too large step is inadvertently required?)

Spontaneous Recovery Let us return to our discussion of the simple extinction of responding to the tone. Suppose that the CS is presented only until responding to it ceases, or perhaps a bit longer. In this case we may avoid the neurotic phases and assume that we have simply done away with the CR to the tone. But that is not the case. Later, whether it be an hour, a day, a week, or much longer, when the tone is presented again, the CR reappears—an effect that Pavlov called *spontaneous recovery*.

In Pavlov's experiments, this proved to him that the connection between the CS tone and the UCS food was not lost during extinction, but was only hidden by the inhibition that had accumulated. Later, when the inhibition dissipated, the excitatory connection was shown to be still there. This occurs because inhibition, for a variety of reasons, was viewed as less enduring than excitation.

Disinhibition If extinction is carried out to the point at which the CS no longer produces a conditioned response, the introduction of a new stimulus, such as a handclap, often produces the

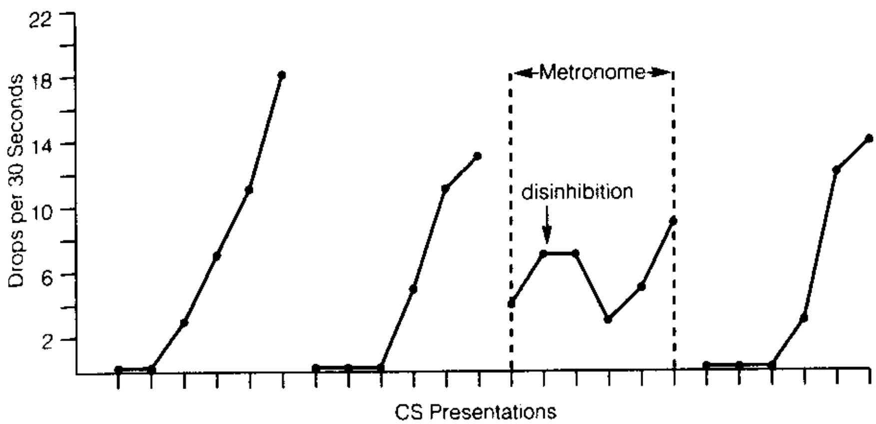

FIGURE 3.7 Pavlov's disinhibition experiment in which he presented a tactile CS with a metronome (Pavlov, 1927, p. 93). The graph shows four presentations of the CS, each three minutes in duration, at intervals of 30 seconds. The metronome was added during the third presentation. Disinhibition appears as increased salivation during the first half of the presentation.

reappearance of the CR. This release from inhibition is called *disinhibition*. Pavlov's explanation for this is too complex to present here; suffice it to say that disinhibition suggests that the strength of the CR has not been decreased to zero during extinction. The excitatory effects of previous conditioning are still there, but the extinction procedure has overlaid the excitatory tendency with inhibition. Figure 3.7 graphs the results of one of Pavlov's experiments with disinhibition.

Extinction Below Zero Recall that Pavlov believed that extinction amounted to the building up of inhibition that acted against the excitation built up during conditioning. Recall also that the repeated presentations of a CS without the UCS (such as food) continued to produce inhibition even after the CR no longer was evident. This was the case in the earlier example of simple experimental neurosis. This means that the tendency to respond not only reduces to zero but goes below zero with continued extinction trials. If this were true, the longer a CS were presented in extinction, the more difficult it would be to produce responding when the UCS was presented again. Pavlov showed this to be the case, as have other investigators since Pavlov's time (e.g., Konorski, 1948; Reynolds, 1964). This event occurs because the more that inhibition has strengthened, the more excitation produced by the CS–UCS pairings is necessary to counter it. The tendency to respond must be raised from a below-zero level.

Inhibition of Delay When a CS (such as a tone) is followed quickly by a UCS (such as food), we have what Pavlov called simultaneous conditioning. The tone and food are presented almost simultaneously, with the tone slightly preceding the food. After such conditioning, it is possible to introduce a delay between the onset of the tone and the food and still produce a conditioned response. The delay period separating the onset of the tone and the presentation of food may gradually be extended to many minutes. Note that during the procedure, delayed conditioning, the CS (tone) is presented and remains on over the delay period until the food is presented.

Initially, and while the delay period is brief, the conditioned response (salivation, bodily orientation, and so on) may begin with the onset of the tone and continue until the UCS is delivered. But as the training is continued and the delay period is increased, the conditioned response appears only after the tone has been on for a while and increases in strength as the time for food nears. The decrease in responding during the early part of the interval was evidence for Pavlov that inhibition was at work. The beginning of the period was an extinction period, thus rendering it inhibitory. The decrease of responding in this situation is called *inhibition of delay*. Pavlov showed that disinhibition was possible, so that the presentation of a new stimulus (such as a buzzer or a trumpet tone) produced responding during this period.

The effects of inhibition were also indicated in the behavior of Pavlov's dogs. Especially when the delay period had been extended to very long intervals of fifteen minutes or an hour, it became difficult to keep the canines awake. When training with such long delays was carried out for too long, the dogs fell asleep because of the accumulation and spread of inhibition produced by the CS. This occurred even in the case of lively, alert dogs, almost as soon as they were placed in the experimental apparatus. In fact, it was most frequent among these lively, active dogs.

Conditioned Inhibition and Differential Inhibition If the tone is followed by food, and then on other occasions another stimulus (such as a light) is presented with the tone but without food, we find that the CR to the tone/light pair quickly disappears. The tone presented by itself still has its expected effect, and the light presented alone has, of course, no effect. The light has become a conditioned inhibitor, and conditioned inhibition is just a case of the more general principle of differential inhibition, or the inhibition that accompanies the formation of a discrimination (or a differentiation, in Pavlov's terms).

The normal method for the training of a discrimination is to alternate presentations of one CS with food, for example, and presentations of one or more other stimuli without food (that is, in extinction). This is Pavlov's method of contrasts, and it is an excellent way to render a stimulus (the negative CS presented without food) inhibitory. The reasons for this will be clear later, when the operation of Pavlov's fields is briefly discussed. The inhibition produced in this way may be disinhibited; differential inhibition was very important in Pavlov's interpretation of the way in which we learn to discriminate objects in our world.

Algebraic Summation A CS may be shown to be inhibitory by observing its effects when it is presented with an excitatory CS. One of Pavlov's methods for demonstrating inhibitory or excitatory properties of conditioned stimuli is called *algebraic summation*. Suppose that we have a tone that has been paired with food and that regularly produces a strong CR. We may present along with it a second stimulus that may be inhibitory because the CR to it has been extinguished, because it has been present during delayed conditioning, or because it has been presented without food during differential conditioning. If the added stimulus is inhibitory, it will reduce the normal response to the tone, and the amount of reduction will depend upon just how inhibitory is the added CS.

In his demonstrations of algebraic summation, Pavlov was careful to show that the effect was not simply due to the fact that a new stimulus was added, but that it was specific to stimuli that had been rendered inhibitory. For example, if the purpose were to show that a negative conditioned stimulus (CS −) was inhibitory by presenting it along with an established positive conditioned stimulus (CS +), it would not be enough simply to observe a decrease in response to the CS +. Perhaps adding any new stimulus to the CS + would have the same effect. Thus, you would be comparing the effects of a putative CS − with the effects of adding some third stimulus, which had not been rendered a CS − or a CS +. This sort of summation may be shown with excitatory stimuli as well; a CS previously paired with food may increase the reaction to the tone.

Evidence for Inhibition

Subsequent research (e.g., Rescorla, 1969) has largely corroborated Pavlov's findings regarding inhibition. However, such research has not provided evidence that extinction per se is sufficient to render a stimulus inhibitory, which Pavlov contended. It may be that this occurs only in a context in which some other CS is presented with a UCS—that is, in differential conditioning. This conclusion is based upon results from experiments in which currently acceptable tests for inhibition are applied. The tendency for extinction alone to produce sleep and its stages still stands, as far as is known, although Pavlov's interpretation in terms of the accumulation of inhibition has not received notice in the United States.

In addition to reconditioning and algebraic summation, another test for inhibition has become popular (cf. Lolordo & Fairless, 1985). This consists of observing actual movement by the subject. For example, locomotion by a rat or pigeon away from a CS− is now considered good reason to call the CS− inhibitory (Hearst & Franklin, 1977).

The Paradox of Inhibition

Pavlov believed that inhibition accompanies presentations of any CS, and that only excitation produced by a UCS counters it. This is particularly true in delayed conditioning, in which a CS is presented and remains present for seconds or minutes prior to the presentation of the UCS. In one example (1927, lecture 14), a dog received CS–UCS pairings of a metronome and food; the metronome preceded the food by 30 seconds and pairings occurred ten minutes apart. The following day the pairings were applied only 90 seconds apart and the salivation CR steadily diminished, trial by trial. By trial 22, only one drop of salivation appeared, although eleven or twelve drops had been typical.

On subsequent trials, no CR occurred and the dog refused to eat the food presented as the UCS. Was this the simple result of too many food presentations in too short a time? No, that was not the case. When a different CS+ for food was presented, the dog salivated and then ate; when no CS was presented, the dog ate "avidly" when food was offered. Evidently, the metronome CS that signaled food had become an inhibitor of both the CR and the UCR to food!

Kimmel (1966) described demonstrations of this effect. In one case salivation was so inhibited that a dog failed to salivate even during normal feeding. In other cases, human subjects showed inhibition of a variety of CRs, typically when the delayed conditioning method was used. Interestingly, he reported that "organism-wide tranquillity" also often occurred.

For example, in a variety of experiments human subjects were presented tones as CSs preceding electric shock. One aspect of the UCR to shock is perspiration, which can be measured as a change in skin conductance—the galvanic skin response (GSR). In Kimmel's experiments, a tone was sounded and remained on for a few seconds, followed by electric shock; the CR appeared as a GSR reading. As trials continued, typically to a dozen or more, the GSR diminished and in some cases even decreased to less-than-baseline levels. Why did this happen?

It was not because subjects adapted to the shock, making it less noxious—any more than the dog stops salivating and accepting food because it is not hungry. To prove this, all we need to do is present the shock without the CS; a strong response occurs. And if we ask subjects to rate the intensity of the shock, they do not report it as less noxious, even when their GSR to it has decreased greatly.

The subjects reacted as they did because the CS specifically inhibited the CR and the UCR. Kimmel could have extinguished this inhibitory effect by presenting the CS alone, without the UCS, a few times. If he then applied the CS–UCS pair, the UCR would be fine and the CR would appear after a few pairings.

The same effect has been shown in human eye-blink conditioning, in which a CS, such as a tone, is paired with a puff of air to the eye. The CR appears as an eye blink produced by the CS and preceding the air puff UCS. After twenty trials or so the eye-blink CR and the UCR to the puff diminish; but all we need do is present the air puff alone and the eye blink UCR is as strong as ever.

These findings provide strong support for learned inhibition, just as Pavlov described it. They also remind us that classical conditioning is more complicated than it first appears, a fact also well known to Pavlov.

External Inhibition

The inhibitory effects described so far are cases of what Pavlov called internal inhibition, since in his view they depended upon the build-up of inhibition in the cerebral cortex. Another effect, which he termed *external inhibition*, occurs when some new behavior is evoked and interferes with ongoing behavior. For example, during the presentation of a tone CS paired with food, a new stimulus, such as the sounding of a fire gong, may prevent or diminish the CR to the tone. This is due to the orientation of the subject toward the new sound and to other bodily movements that interfere with the reaction to the tone.

Pavlov's Brain: The Fields on the Surface of the Cortex

Pavlov's interests were not concentrated on the analysis of simple conditioned responses, but on the brain mechanisms he believed were responsible for our behavior and experience. Pavlov was trying to discover the principles that governed the action of the cerebrum, much as Sherrington had done with the spinal cord. Following Sherrington, Pavlov felt that the interaction of excitatory and inhibitory influences was basic to the workings of the cortex. Years of experiments led to the following fairly simple conception (Pavlov, 1927).

Presenting specific kinds of stimuli produces activity (excitation) in the brain centers that represent those stimuli. For example, food in the mouth of a hungry organism produces excitation in the *alimentary* (eating/digestive) *center*. Other stimuli presented along with such stimuli, such as the sight of food, a tone, or whatever, produce milder excitation in their respective brain centers. Since excitation occurs simultaneously in the food (UCS) and the tone (CS) centers, for example, a link forms between them. Excitation from the stronger (food) center flows to the weaker (tone) center and the tone thus becomes an excitatory CS, producing the effect formerly produced only by food.

As the tone and the food are paired repeatedly, strange things happen as the tone becomes more excitatory. Although the excitation is still weak, it irradiates, or spreads across the cortex. During this stage, a variety of tones or other stimuli may produce a CR, since the spreading excitation may include their cortical representations. The response to them will be weak, since the excitation spreading from the CS center is weak. With continued presentations of the tone and food, the tone becomes moderately excitatory and irradiation is replaced by *concentration*. The concentration of excitation at the cortical representation of the tone means that only those stimuli very similar to the tone (such as other tones) will elicit a CR, and the magnitude of the CR will depend upon the degree of similarity to the original tone. Excitation concentrates most strongly at that point and diminishes with distance from it.

Finally, after extremely lengthy training, excitation associated with the tone becomes extremely strong and once again irradiates. This stage, at which responding again occurs to a wide range of stimuli, may never be reached. Figure 3.8 diagrams the stages at which irradiation and concentration take place during discrimination.

At the stage in which irradiation is replaced by concentration, as both excitation and inhibition increase to medium strengths, something new occurs. A presentation of CS+ causes a decrease in the response to the CS− that follows, so responding is lowest immediately after CS+ and increases while CS− is present. A presentation of CS− produces the opposite effect on the succeed-

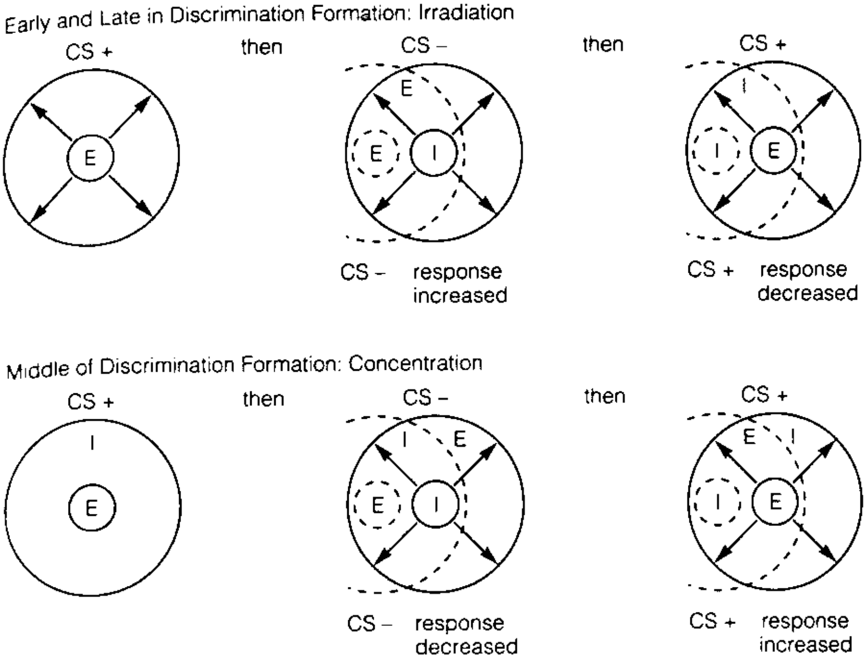

FIGURE 3.8 A diagrammatic representation of Pavlovian fields. The upper half of the figure shows postulated processes early and late in the forming of a discrimination. Presentation of a CS+ (upper left) produces irradiation of excitation, represented by the radiating arrows. A subsequent presentation of a CS− (upper center) produces inhibition and its irradiation, but the cortical representation of CS− (the circled *I*) falls on the remnant of the excitatory surround from CS+. This excitation subtracts from the inhibition produced by CS− and tends to increase responding to it. The upper right figure shows a subsequent presentation of CS+; in this case the remaining inhibition from the previous CS− tends to diminish responding to CS+. The lower half of the figure shows the postulated processes midway in discrimination formation, during which concentration replaces irradiation. A presentation of CS+ (lower left) produces excitation at the cortical representation of CS+, as well as an inhibitory surround. A subsequent CS− (lower middle) falls on the remnant of this inhibitory field, which tends to further diminish responding to CS− (negative Pavlovian induction). The inhibitory center at CS− is surrounded by an excitatory field, and the remnant of this sums with the excitation produced when CS+ again appears (lower right). This augments the response to CS+ (positive Pavlovian induction). Sherrington discovered similar effects in spinal cord activity. His *simultaneous induction* was equivalent to irradiation, and *successive induction* was similar to Pavlovian induction.

ing CS+; the response to CS+ is augmented and declines during its presentation. These sequential effects are called *Pavlovian induction*—the former being negative induction and the latter positive induction (see Nevin & Shettleworth, 1966; Malone, 1976). Pavlov attempted to explain these effects in terms of excitatory and inhibitory fields in the cerebral cortex of the brain. Figure 3.9 compares the results of positive and negative induction in an illustrative experiment by Pavlov.

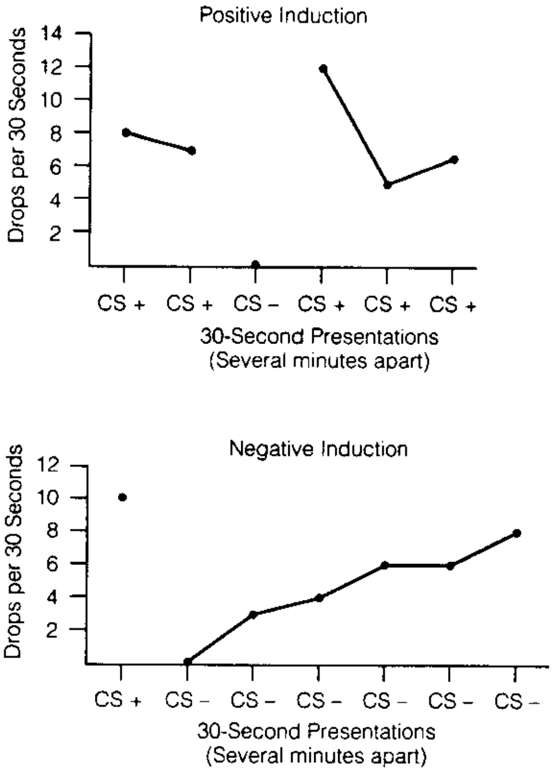

FIGURE 3.9 Positive and negative induction (Pavlov, 1927, pp. 189, 198). The upper panel of this figure illustrates positive induction. A CS + (tactile stimulation of a dog's forepaw) was repeatedly paired with a food UCS. A CS – (tactile stimulation of a hind paw) was established by presenting it with no UCS. The data show responding when the CS + was presented twice, followed by presentation of the CS –. The salivary CR to the next presentation of the CS + was elevated (twelve drops), compared with previous levels of eight and seven drops.

The lower panel illustrates negative induction. The experiment, performed by Pavlov's assistant, Dr. Krjishkovsky, included an already established CS + and CS – (tone and tone paired with touch on skin). The UCS was a mild solution of acid. A presentation of the CS + alone produced a CR of ten drops. When the CS – was presented, responding was suppressed (negative induction). The CR increased in magnitude during subsequent presentations, showing the gradual fading of negative induction.

The Significance of Pavlovian Fields

Pavlov's model specifies three stages in the formation of discriminations learned by dogs. However, the general principles he described may well be operating in the daily lives of dogs and us, as we learn to sort out the objects of the world around us. We react one way to highly familiar objects: For example, I have seen my old coffee cup so often and in so many contexts that I can make an absolute identification of it. It produces strong excitation, in Pavlov's terms, at its cortical center, and this excitation concentrates, producing the immediate recognition.

There are objects to which we respond less firmly, though, and this becomes evident under unusual conditions. For example, darkness or fog or fatigue may require more care in dealing with objects, even when those objects are familiar ones. If the objects are less familiar, even more care is required. For instance, one must take more care discriminating the pavement from the ditch when driving in a rainstorm at night, when mistakes are more easily made and may be costly.

Between these extreme cases, which represent the third and the first stages of discrimination formation, lie the more common experiences of the intermediate, second stage. This is the stage when discriminations are formed and reliable identifications are made but when comparisons help strengthen the discrimination. For example, the two leading brands of cola do not taste exactly the same, and the difference in their tastes is never more evident than when a sip of one closely follows a taste of the other. In any situation in which we wish to accentuate a difference, we find that alternating the objects involved aids us. Consider for a moment how this represents Pavlov's second stage of discrimination formation, in which induction effects accentuate the reaction to the following stimulus. This may be the case in all of our discriminations where the objects involved are not quite unfamiliar (the first stage) and are not overly familiar (the third stage). Pavlov's fields and their changes as training progresses thus seem compatible with everyday life.

Mach Bands Pavlov's fields consisted of excitatory or inhibitory centers and surrounds of the opposite signs; at least they assumed that form while discriminations were being formed (that is, neither very early nor late in training). Several researchers have noted that such fields bear similarities to the *neural unit model*, first proposed by Ernst Mach during the nineteenth century and recently adapted by workers in sensory physiology, such as Bekesy (1967), Ratliff (1965), and Hubel and Wiesel (1959). Briefly, the neural unit model assumes that any stimulation on a receptor surface (for example, the retina or skin) produces a zone of excitation at the stimulated point and a zone of inhibition surrounding it. Elaborations of such units also form inhibitory centers and excitatory surrounds (Ratliff, 1965).

Before we return to the simple version of Pavlovian conditioning, I should point out that scientists are now quite certain that electrical fields do not operate on the surface of the cortex as Pavlov suggested they might (e.g., Lashley, Chow & Semmes, 1951). But even though Pavlov's model may not be in direct correspondence with brain events, it has some general features in common with later theories of neural networks (Smolensky, 1988).

Summary

This section has included a great deal of seemingly diverse information, all of it comprising the basics of Pavlov's theory. The first subsection introduced the important terms and phenomena of Pavlovian conditioning, presented as they are construed by contemporary psychologists. Pavlov and later researchers studied acquisition and extinction with a variety of specific preparations, with the original salivating dog largely replaced by the blinking human or rabbit. Conditioning can be excitatory or inhibitory, depending upon whether the CS signals a forthcoming UCS or its absence, and the effects of conditioning may spread so that other CSs similar to that used in training produce CRs. The way in which such CSs are discriminated from the original CS as training progresses is still of great interest, as it was in Pavlov's day.

An effective CS must ordinarily evoke a reasonably strong UCR; this seems not to be the case in sensory preconditioning, although even in that case it is certain that some UCR is evoked. Almost anything, either inside or outside the body, may be used as a CS. A CS and a UCS may be paired almost simultaneously, or there may be a long delay between CS and UCS. If the CS is presented and removed long before the UCS appears, a presumed trace of the CS persists in the nervous system to bridge the gap. Backward conditioning, in which the UCS precedes the CS, eventually renders the CS inhibitory.

Psychologists still are concerned over what is learned in classical conditioning; there is evidence for both S-S connections and S-R connections. There is strong evidence to show that the UCS in classical conditioning does not act in the same way as a reward in instrumental conditioning. Omission procedures provide the most striking evidence that the CR is not simply maintained by the reward of the UCS. Despite the fact that the UCS and rewards in instrumental conditioning do not act in the same way, the old distinction between classical and instrumental conditioning as two fundamentally different forms of learning is not universally accepted.

Pavlov's views on the functioning of organisms were influenced greatly by Sherrington's analysis of the integrative action of the spinal nervous system. Pavlov adopted many of Sherrington's major principles, and we find the emphasis on *simultaneous* and *successive induction* and the importance of excitation and inhibition throughout his writings.

Pavlov presented many lines of evidence for the existence of inhibitory effects in the workings of the brain. Most of this has been substantiated by later researchers. Inhibition may account for spontaneous recovery, for extinction-induced sleep and psychopathology, and for the pattern of responding during delayed conditioning. It appears that extinction may progress "below zero," that disinhibition is possible, and that excitatory and inhibitory CSs may algebraically summate. The best method to render a CS inhibitory is to use it in discrimination training, along with a CS paired with a UCS.

Pavlov's decades of research led him to propose a model of brain function in terms of fields of excitation and inhibition on the surface of the cortex. During discrimination training, excitation and inhibition form at the cortical representations of CS + and CS − . Early and late in training, this excitation and inhibition spreads (irradiates). Otherwise it concentrates, leaving a surround of the opposite sign. This accounts for Pavlovian induction. Pavlov's fields are ever changing, but the general principle suggests that both excitation and inhibition are always present in our reactions to stimuli.

3. CRITICISMS OF PAVLOV'S THEORY

In the final section of this chapter, we will discuss some of the ways in which classical conditioning influences our daily lives. That influence exists whether Pavlov's theory was correct, and it exists whether the theories of American classical conditioning are correct. First, however, we will briefly mention criticisms of Pavlov's views and of the use made of the CR in the theories of early American psychologists.

Criticisms of Pavlov's Specific Model of Brain Physiology

Pavlov's model supposes that fields of excitation and inhibition operate on the surface of the cortex in the ways described earlier. Such a view is seemingly at odds with current notions of neural activity, which emphasize the transmission of neural impulses along neurons and across synapses. This probably would not seem a great problem to Pavlov, who characterized his model as "a schematic" version of the neural processes involved (Pavlov, 1927); in any event, it is not difficult to make a synaptic network act in the ways in which Pavlov's fields acted (e.g., Thompson, 1965).

Konorski (1948) described a host of data collected since Pavlov's early researchers. The data pretty much support the original model, although Konorski makes some modifications of Pavlov's theory in his translation to a more traditional brain model that does rely on ordinary synaptic transmission instead of fields. Valenstein (1970) provides a good assessment of Pavlov's neurology and its plausibility.

In addition, we have discovered that Pavlovian induction occurs during operant (instrumental) discrimination learning and that its characteristics are as Pavlov described them (e.g., Nevin & Shettleworth, 1966; Malone, 1976). Few researchers, however, have systematically tested Pavlov's theory of how induction takes place (Mackintosh, 1974).

Criticisms of Pavlovian Conditioning as the Basis for All Learning

Pavlov never suggested that all behavior and experience is merely the sum of accumulated conditioned responses (e.g., Pavlov, 1932), although many others *did*. Watson was intrigued with that possibility and mentioned several times in his writings that the CR may be the unit from which all else derives (Chapter 4). Floyd Allport (1924) made bold claims concerning the importance of the CR as such a unit and provoked a torrent of criticism over the years. Hull, a highly influential theorist, also relied on the conditioned response as the ultimate unit of analysis, as we will see in Chapter 6.

It may seem difficult to imagine just how someone could suggest that all behavior and experience is built from CRs, but the argument does have some merit. One must begin with the conviction that we are, after all, biological beings and that we come with a set of inborn reflex reactions. We originally react (with UCRs) only to biologically relevant things, such as food in our mouths, water, warmth, and stroking. These things are

TABLE 3.4 Example of Higher Order Conditioning

CS5: knights, heroes	
CS4: praiseworthy behavior	
CS3: praise	CR: attention, pleasure, and so on
CS2: attention	
CS1: parent	
	UCSs: food, water, warmth, stroking
	UCRs: attention, pleasure, and so on

accompanied by a parent (or other caregiver), who becomes a CS evoking positive CRs. These CRs generalize to other adults, and second-order CRs develop. Table 3.4 provides an example of higher order conditioning and shows how simple UCRs may form the basis for higher motives and behaviors.

Thus, the parent's presence is not sufficient as a CS. The child learns that the parent must be paying attention to him or her. The child receives food (and so on) only then. The child discriminates parent-plus-attention from parent alone, and *attention* becomes a CS for food and cuddling. Then the child finds that an angry parent, while giving attention, less reliably provides UCSs (food and comfort), so *praise* comes to be a third-order CS.

The parent shows the child pictures of shiny buttons (which act as UCSs to capture attention) worn by knights and soldiers, who therefore also (as CSs) capture the child's attention. The knight or soldier appears in a context of praiseworthy endeavors and the shiny button comes to signify (as a CS) praise, honor, and virtue. The child learns to name the knight, because utterances that sound like *knight* are followed by the UCS (parent saying *knight*); and language is built up out of a set of CRs joined together somehow in series.

As a distant precursor of Pavlov put it, this process accounts for "a young girl's tremblings at the first thoughts of love, . . . Newton's creating universal laws, . . . and the behavior of a man with an ideally strong will, acting under some high moral impulse, and perfectly conscious of everything he does" (Sechenov, 1863).

We will see that the CR plays an exceedingly important part in our attitudes, in "psychosomatic" medicine and in the origin of phobias (pathological fears). But as the unit out of which all behavior and experience is constructed, it falls short by quite a bit. The appeal that the CR had for early American psychologists stems from their desires toward reductionism—the analysis of the complex into some sort of units assumed in advance. This was not Pavlov's way, and the pros and cons of reductionism will be clearer in Chapter 6, when we discuss Hull.

4. OTHER ASPECTS OF CLASSICAL CONDITIONING

Classical conditioning affects our reactions to a host of common occurrences of daily life. It explains a number of common likes and aversions that span a lifetime, and it plays a large role in determining our state of health.

Classical Conditioning in Daily Life

Decaffeinated coffee wakes me up, as does regular coffee, as long as I don't drink decaffeinated coffee exclusively. People with oddly bright blue eyes looking straight at me bring to mind a particular brand of cigarettes. Richard Nixon reminds many people in my generation of the presidential seal. For some people, prune juice produces its customary cathartic effect as soon as they taste it. The word *inhale* produces constriction of peripheral blood vessels in the arm. Gloomy gray days make us feel tired and dull. Mealtime produces an upset stomach in some people and a feeling of warmth and security in others.

All of these are instances of classical conditioning, which is so common in our lives that we pay little attention to it. But all of the examples illustrate the central rule that defines classical conditioning: If two elicitors are paired reliably in a certain way, the weaker of the two comes to produce (more or less) the reaction formerly produced only by the stronger elicitor. As the tone produces the salivation appropriate to food in the mouth, the taste, smell, and appearance of coffee come to produce the reaction originally produced only by the caffeine. The blue-eyed people on billboards draw our attention; later, the brand of cigarettes that appear with them in the ads draw our attention (or so the manufacturer hopes). A childhood in which gray days must be spent indoors with nothing to do may lend the feelings of those times to the gray sky (cf. Buck, 1988).

All of these effects occur whether we want them to or not and whether we are aware of it or not. When we inhale, the peripheral blood vessels in our limbs constrict; they also do so when we say or hear the word *inhale*. Classical conditioning is important because it is an automatic process. We may dismiss (as countless people have) the salivation of the dog when the tone is sounded. The tone predicts food and makes the dog anticipate it; he salivates because he expects food—hardly an occurrence of importance. The point is that the dog salivates whether it wants to or not, whether it anticipates or not. In fact, in many cases of classical conditioning, awareness of what is to come plays no conceivable part. Before describing such cases, consider the following example.

Classical Conditioning as an Explanatory Device

A good deal of what seems very complicated human behavior and experience may result from the classical conditioning that affects us every day of our lives. Such examples as the salivating dogs seem far removed, but the same principle may be operating in our own behavior and experience every day of our lives. Consider the following example of a family in which the parents have chosen breakfast and dinner gatherings as a time for criticism and reproof of a child's current activities. Suppose that this pattern continues for a number of years and produces effects on the child that last for years after. Assuming that criticism of this kind elicits strong bodily visceral/emotional reactions, we have a UCS producing a UCR. Anger, shame, sadness, and discomfort on the child's part is accompanied by stomachaches, perspiration, headaches, and other bodily changes. These reactions are also accompanied by a host of cues that become conditioned stimuli. The sight and sound of the parents, the furniture present, the stimuli accompanying food, the sensations of food passing through the digestive tract, and so on (Buck, 1988).

Suppose, as is likely, that the parents are not criticizing the child during the whole day; their support and encouragement at other times renders them unreliable predictors of impending stomachaches and other aspects of the UCR. Similarly, time is spent in the dining room in the absence of the parents and the cues present there do not act as good predictors. The only fairly reliable predictor of emotional distress and its bodily manifestations is the sight, taste, and smell of food and the stimuli the child carries inside—the sensations of food passing through the digestive tract. Aside from the sensations that go with a very full or a very empty stomach, the child is largely unaware of these sensations, but that is not really important. The body is aware, and such sensations can come to elicit emotional distress.

Imagine the effects in later life, especially since conditioning in which the CS is an event within the body is extremely durable (Razran, 1961). Later aversions to food and eating (and other situations and activities) could later appear and would no doubt be attributed to an endless variety of psychic disturbances. A childhood that includes encouragement and support from the researchers showed that this was not the case; muscle tensing and hyperventilation (deep breathing) by themselves produced no noticeable increase in oxygen consumption.

Also interesting was their finding that the CS (command) that occurred two minutes before the UCS (exercise) eventually resulted in the CR (oxygen use) appearing only during the minute before exercise. This is the expected result in delayed conditioning, in which the UCS comes some time after the onset of the CS. (A metronome, which also accompanied the exercise, was on during the interval between the CS and the UCS. The metronome acted as a part of the CS, so the procedure was delayed conditioning rather than trace conditioning.) As in other cases of delayed conditioning, it was possible to disinhibit "inhibition of delay" and reinstate a high rate of oxygen consumption during the first minute. This was accomplished by giving the subjects a small drink of coffee or of alcohol in tea, neither of which affected the consumption of oxygen under other circumstances. But the drinks did act as disinhibiting stimuli, and they raised the level of consumption of oxygen during the first minute. Thus, delayed conditioning here was equivalent to delayed conditioning in more familiar procedures, such as when the bell precedes the food to be given to the salivating dog.

In another example described by Bykov, a mild solution of hydrochloric acid (weak enough to just provide a bitter taste) was injected occasionally into the small intestine of a dog through a fine plastic tube. On other occasions, a weak saline solution was injected. The intestine had been surgically connected to the catheter so there was no chance the dog could taste the fluids. Only the small intestine "knew" what was being injected and you must agree that one of the great blessings of life (for us and for dogs) is that we are allowed to ignore our intestines completely! Except in extreme illness, we haven't a clue what they are doing and we leave their daily operation up to them.

It is difficult to believe that the dog was aware of the few drops of fluid placed in its intestine, and it surely could not tell whether the acid or the saline was injected. The contents of the small intestine are not tasted, as far as we know, but they are nevertheless discerned by the body in some way. Paired with the injections of acid was an electric shock to one of the dog's hind feet. The dog was aware of this. Among the components of the UCR to shock is a brief elevation in heart rate. Presentations of the salt solution were not paired with shock. Within sixteen trials the injection of the acid became a CS, producing changes in heart rate, and the salt solution produced no effect. Surely the dog was not aware of the acid injection, but something was telling the foot and the heart that the shock was coming.

A practical application of classical conditioning of an internal organ was reported by Ince, Brucker, and Alba (1978), whose subject was a 40-year-old paraplegic man. He had suffered a complete severing of his spinal cord a year before as the result of an accident and, among other problems, had lost all control over urination. Ince et al. knew that a fairly intense electric shock to the lower abdomen can elicit reflex urination; hence, the shock acts as a UCS. What if the shock were paired with a CS? Could the patient use the CS to control urination?

A mild shock to the inner thigh was used as a CS, paired with the intense shock to the abdomen as a UCS. Conditioning did indeed occur; the CS alone produced a strong urination CR. Thereafter, the patient was able to control urination by applying the CS and eliciting the CR of urination. Interestingly, both thigh and lower abdomen were below the body areas controlled by the patient's functional (upper) spinal cord; this means that conditioning occurred without the brain's involvement.

Occasional sessions in which CS–UCS pairings occurred were necessary to maintain the CS's effectiveness. However, the patient was able to apply the CS hundreds of times (over days and weeks) without extinction occurring. This illustrates the unusual resistance to extinction of visceral conditioning.

Ader and Cohen's Lupus Studies Another example of the medical applications of interoceptive conditioning was reported by Ader and Cohen (1982), two researchers at the University of Rochester Medical School. They were studying ways of treating the disease systemic lupus erythematosus, which is a malfunction of the body's response to invading microorganisms and other foreign proteins. This illness, usually called lupus, amounts to an exaggerated response of the body's immune system, so that healthy tissues are destroyed and death results.

To study the possible ways of treating this disease, scientists bred a strain of mice that are genetically prone to the disease. These mice usually die within eight to fourteen months of age. If some treatment can be discovered to prevent the death of such mice, we could possibly have the cure that could prevent the death of humans stricken with lupus.

The drug cyclophosphamide can postpone lupus by suppressing the body's autoimmune response. Unfortunately, this is not a practical cure, since the suppression of the autoimmune response leaves us vulnerable to whatever germ may come along and even an ordinarily harmless infection could do us in.

Ader and Cohen treated three groups of these special mice with either cyclophosphamide injections or injections of salt water. The groups were as follows:

> C100: The mice in this group received a drink of saccharine water followed by an injection of cyclophosphamide once a week for eight weeks.
>
> C50: The mice in this group received the same treatment as those in the C100 group, except that half of the injections contained salt water rather than cyclophosphamide.
>
> NC50: This group received the same treatment as the C50 group, except that the saccharine water and the injections of salt water or medicine were never paired. The injections were given on different days.

Mice in a control group were given no medicine but received drinks of saccharine and saline injections (unpaired) once a week.

The cyclophosphamide given was not enough to prevent death indefinitely, so all of the mice died, as was fated by their genetic makeup, which brought their unfortunate disease. But which mice died first, which died last, and which died second and third in order? Group C100 subjects lived longest, which is not surprising in view of the large doses of medicine they were given. And the mice in the control group lived the briefest; again, this is not an amazing result, since they received no cyclophosphamide.

What was interesting was the difference in the life spans of the C50 and the NC50 groups, both of which outlived the controls but died sooner than did the C100 group. Both the C50 and the NC50 groups were given the same amount of cyclophosphamide, the same doses of saccharine water, and the same number of injections of salt water. Yet, the C50 group outlived the NC50 group by almost a month and a half (on the average). This amounted to an increase in longevity of about 25 percent. Why should this be?

The secret lies in classical conditioning of the autoimmune response. Group C50 always received saccharine water followed by an injection. Half the time the injection was cyclophosphamide, a UCS that produced a UCR suppression of the autoimmune response. What happened when the saccharine water was added as a CS?

Water taste (CS)
cyclophosphamide (UCS) → suppression of autoimmune system (UCR)

The sweet taste soon produced a CR suppression of the immune system whenever it appeared, including when it was presented with saline injections. The mice in the C50 group effectively were getting more medicine than those in the NC50 group. For the animals in the NC50 group, the sweet taste and the cyclophosphamide were never paired and thus no conditioned response appeared.

In their account in *Science* (1982), Ader and Cohen point out the significance of their findings for human sufferers. They suggest that classical conditioning may have many useful applications in the form of such placebo effects. For example, suppose you are dying of a hideous disease, such as some kind of organ cancer and that your life is being prolonged through chemotherapy. The medicine that keeps the cancer in check is very harmful itself; you probably have heard about the horrible side effects of chemotherapy.

What if your dose of medicine could be cut in half, as the dose of cyclophosphamide was cut in half for the mice? Could a distinctive stimulus be paired with the medicine on some occasions and with harmless salt water on other occasions? Would a CR appear, as was the case for the C50 mice? Could the medicine thus have its good effect with half the previous dose, so that unwanted side effects could be reduced?

Of course, the usefulness of the described procedure depends upon what effects of cyclophosphamide or other drugs turn out to be conditionable. Ader and Cohen assumed that the beneficial effects will appear as CRs, sparing the patient the ill effects. But there may be cases in which unwanted effects also appear as CRs, perhaps even more strongly than the beneficial effects. Still, the possible great benefits of such treatments warrant further research.

Countless experiments have been done with both human and animal subjects, showing that bodies are conditionable, even if we have not the slightest awareness of what is going on. Russian researchers, such as Bykov, firmly believe that the cerebral cortex is involved in such conditioning and that sensory information from throughout the body is sent to the cortex, although we are utterly unaware of most of it.

Drug Addiction A good deal of work has been done in the United States investigating the part played by classical conditioning in drug addiction. Horsley Gantt, at the VA hospital in Perry Point, Maryland, did much of this work until his death in 1980. Interestingly, he was the translator of Pavlov's (1928) original lectures. For an example of classical conditioning and drug addiction, consider the demonstration reported by Spragg in 1940, in which chimpanzees were addicted to morphine. After a time without morphine the chimps showed obvious withdrawal symptoms, much like those shown by human addicts. Under these conditions, morphine acts as a UCS producing a UCR (the ending of withdrawal symptoms).

Morphine had been injected using a hypodermic syringe, and it is reasonable to assume that the sight of the syringe and the injection itself had become conditioned stimuli. When Spragg injected salt water, he found that this was the case. The CR brought on by the injection eliminated all signs of withdrawal in the chimpanzees for up to half an hour. Further applications of classical conditioning to drug addiction will be discussed in Chapter 9 when we consider the interesting model of Solomon and Corbit (1974) and the research of Siegel (e.g., 1985).

Semantic Conditioning

One interesting application of classical conditioning, described by Razran (1961), deals with what we usually call meaning in language. Meaning may be defined in a number of ways, such as the associations attached to a word. For example, one definition for the meaning of *tree* is the list of associates commonly produced by the word (for example, green, leaf, wood, shoe). Some theorists, including Collins and Quillian (1969), believe that the order and the speed of production of associates is important in assessing meaning.

Semantic conditioning is a way of assessing the similarity of meaning of words and symbols, as well as what Razran called the "meaning load" carried by parts of a sentence. We will consider three aspects of semantic conditioning: semantic generalization, phonetic generalization, and assessing "meaning load."

Semantic Generalization In semantic generalization procedures, a CR is established to a word, a sentence, or a numerical expression CS, and a second CS typically is made inhibitory (no UCS paired with it). The UCSs include food, a cold disk placed on the skin, and electric shock. Razran presented the data obtained from a thirteen-year-old boy, Yuri, who was conditioned to salivate to sentences and numbers. For example, after the Russian words for *good* and *bad* were established as CS+ and CS−, respectively, a number of sentences were presented. Yuri salivated when a sentence such as "The Russian army was victorious" or "Leningrad is a beautiful city" or "The enemy army was destroyed and annihilated" was presented. But Yuri did not respond much to sentences that referred to "bad" things, such as lazy or disobedient students. The initial training with "good" (CS+) and "bad" (CS−) made it easy to assess what Yuri considered good and bad.

It is not difficult to think of practical uses for this procedure, especially when applied to attitudes that may be unconscious or that the subject does not wish revealed. The CR to the original CS generalizes to other stimuli that are similar in meaning (that is, semantics) for the subject.

Table 3.5 shows semantic conditioning with numerical stimuli. In one case, Yuri was conditioned to respond to the number ten (CS+) and not to the number eight (CS−). Note the difference in response when the expressions presented represented a difference, a sum, a quotient, or a product of ten or eight. The second case shows responding to the items on the left when the CS+ was eighteen and the CS− was fourteen. The latencies given show the pause before salivation began; note how the latency increased with the difficulty of the operation. The final example is especially interesting.

TABLE 3.5 Salivation of 13-Year-Old Yuri to Arithmetical Operations

Salivation After Conditioning to 10 *(CS+) and* 8 *(CS−). (Data do not include all that appeared in Razran's [1961] Table 2.)*

Stimulus	*Drops in 30 seconds*
83 − 73	15
20 − 12	2
1000/100	18
48/6	3
4 × 2	2
112 − 102	11
470/47	11
99 − 91	3
88/11	3
35 − 25	25

Salivation After Conditioning to 18 *(CS+) and* 14 *(CS−).*

Stimulus	*Drops in 30 seconds*	*Latency (sec)*
9 + 9	18	2
90/5	13	6
72/4	9	11
2232/124	2	7.8

Razran, 1961

Phonetic Generalization *Phonetics* refers to the sounds of language, whereas *semantics* refers to meaning. The Russian researchers discussed by Razran (1961) have repeatedly found that younger or retarded children generalize phonetically: After training to respond to the CS+ *tree*, they respond to words such as *bee* and *tea*, rather than to *bush* and *pine*. Older children and adults tend to generalize semantically; that is, from a CS+ to items similar in meaning (for example, *tree–bush*).

The shift from phonetic to semantic generalization also depends on the stage of training. In one experiment adult subjects received CS–UCS pairings in which the CS was a word and the UCS was a cold disk placed on the arm. When test words were presented, the vasoconstriction CR occurred to similar sounding words during early trials (phonetic generalization). But, after 25 trials, the CR occurred to new words similar in meaning (semantic generalization). When the subjects were given tranquilizers, phonetic generalization returned. In the United States, such an effect would be called differences in the level of processing (e.g., Bower & Hilgard, 1981).

Assessing Meaning Load The final type of semantic conditioning research is interesting indeed. The following example involves the use of classical conditioning to estimate the relative contributions of parts of a sentence to the meaning of the whole, but other applications are obvious. For example, Razran (1961) described an experiment in which 30 college students were presented sentences as positive CSs and electric shock to the fingers as a UCS. The finger withdrawal CR was then measured when different parts of the sentences were presented as CSs and no electric shock occurred. The students' CRs were used as an indicant of meaning of parts of the sentences. If a sentence part acts as a strong CS + it is judged to be meaningful.

The results appear in Table 3.6. The slashes indicate which parts of each sentence were presented alone. The percentage of CRs that occurred appears in parentheses. Data is from the first trial for each subject.

TABLE 3.6 Conditioned Response to Sentence Parts

I am switching on /	the shock.	
(100%)	(100%)	
The manuscript /	was read.	
(0%)	(0%)	
The student /	passed /	the examination.
(10%)	(87%)	(50%)

Razran, 1961

Note that in the first example, a CR occurred for both sentence parts; it is reasonable that each part carried the meaning of the whole sentence. In the second example, CRs occurred when the whole sentence was presented, but not when either half appeared, since neither had much meaning alone. In the third example, the second sentence part (the verb *passed*) received the most responses, and the third part also elicited frequent responses. On the other hand, little meaning (or CRs) occurred for the first part of the sentence. The second and third parts make it likely that a student is involved, so it is reasonable that the first part does not evoke much response.

There are many applications of this procedure. Razran suggested that the method be applied to the study of unconscious content, Freudian symbolism, advertising, propaganda, and other areas. You probably can think of other applications.

Summary

Classical conditioning affects us constantly. This is shown in the CR produced by an occasional cup of decaffeinated coffee, typical reactions to the figures on billboards, and the life-long eating patterns that grew from listening to parents' criticism during mealtimes. Because classical conditioning affects us daily and can influence our behavior so dramatically, it can actually be applied for this purpose.

Interoceptive conditioning is classical conditioning in which a stimulus is applied to the structure of the body. Soviet psychologists showed that interoceptive conditioning has important medical applications and very recent work in America shows that classical conditioning plays a large part in our reactions to medicines. Any organ or system of organs can be conditioned if a UCS is available. By pairing a convenient CS with an appropriate UCS, we can influence the organ or system involved, whether it be the kidney or the body's metabolic rate. Classical conditioning may also be used to treat drug addiction.

Medicines act as UCSs. Therefore, the sight or taste of medicine or even the label *medicine* can act as a CS. This no doubt accounts for placebo effects, the beneficial effects of sugar pills that a patient believes to be medicine. Placebo effects also occur when the subjects are infant mice and no conception of taking medicine is likely to be in the patient's heads. This points up the fact that classical conditioning need not require awareness that it is occurring. If we assume that the dog salivates because it anticipates food we must also say that the small intestine anticipates shocks!

It should by now be apparent that classical conditioning plays a role in everyday experience; it does not apply only to the case of the tone and the salivating dog. It shows that the entire body is alive and that its organs are affected by our experience, however ignorant of our lives we may believe them to be. Bykov (1957, p. 27) quotes Maupassant in this regard: "Your feet, your muscles, your lungs, all your body has not yet forgotten and keeps saying to the brain, when the brain wishes to lead it along the same hard path: No, I shall not come, I have suffered too much on this path. And the brain accepts the refusal, obeying without arguing the silent language of its comrades." Words, phrases, and sentences act as CSs, as shown in studies of semantic conditioning. Classical conditioning may therefore be used to assess attitudes and meaning and even to explore the unconscious.

GLOSSARY

Acquisition The development of an ever-stronger and more reliable conditioned response (CR) through conditioning. (See *extinction.*)

Algebraic summation Method used by Pavlov to demonstrate the inhibitory and excitatory properties of CSs by pairing them with other CSs. For example, an inhibitory CS introduced along with another CS will cause a decrease in responding to the latter. A positive CS presented with another positive CS should produce a response greater than that to either of the individual stimuli. This method also was used by Rescorla (1969).

Alimentary center Brain center aroused when eating occurs, in Pavlov's theory of conditioning. The alimentary center was strongly activated by food in the mouth (a UCS), and part of this activation spread to the brain centers corresponding to CSs simultaneously present.

Appetitive Category of UCSs. This adjective describes stimuli that we judge to be pleasant, adaptive, or otherwise beneficial for the organism.

Aversive Category of UCSs. This adjective describes stimuli that we judge to be unpleasant, dangerous, or otherwise not beneficial for the organism.

Backward conditioning A conditioning procedure in which the UCS precedes the CS. This was formerly thought to lead to no conditioning, but it has been recognized as the chief means for producing inhibitory conditioning.

Classical conditioning Procedure whereby two elicitors are paired in such a way that the weaker precedes the stronger by a second or more (ideally) and so that the weaker stimulus reliably predicts the stronger. Conditioning is said to occur when the weaker stimulus produces a response similar to that produced by the stronger. For example, the taste of coffee, associated with the effects of caffeine, may actually perk us up. (Most coffee drinkers feel perky long before the caffeine can have a real effect on the body.)

Concentration Process that occurs during classical conditioning, specifically during discrimination learning. Early and late in training, excitation and inhibition associated with CS + and CS − irradiate (spread). Midway in training, excitation and inhibition concentrate, or remain close to their respective brain centers. Concentration is the opposite of irradiation.

Conditioned response (or reflex)/CR Response evoked by a CS after pairing in a specific way with a UCS. The CR resembles the response to the UCS, not the original response to the CS. For example, the sight of a cut onion at a distance may produce a CR secretion of tears.

Conditioned stimulus/CS Weak elicitor that is paired with a stronger elicitor in such a way as to acquire the power to evoke the response originally evoked by the stronger elicitor (UCS).

Conditioned suppression Procedure used to investigate the inhibitory and/or aversive properties of stimuli. For example, a stimulus previously paired with shock may be presented while subjects are bar pressing or proofreading. If the rate of the latter performances is decreased during the presentation, the added stimulus is judged inhibitory.

Delayed conditioning Classical conditioning procedure in which the CS is presented, remains present, and is later followed by the UCS. With training, responding decreases during the early part of the delay interval.

Disinhibition The release from inhibition produced by a new stimulus, such as a handclap or a trumpet blare. This is evidenced by the appearance of responding in the presence of an inhibitory CS.

Differentiation Pavlov's term for discrimination formation. It includes both the discriminating of stimuli and the associating of UCSs with appropriate stimuli.

Equalization phase Stage described by Pavlov that occurs during prolonged extinction training. During this phase, both strong and weak CSs produce the same magnitude CR.

Excitatory conditioning Classical conditioning in which a CS reliably predicts the occurrence of a UCS. This is the opposite of inhibitory conditioning, in which the appearance of the CS means that the UCS is not coming.

Experimental neurosis Bizarre behavior brought on by the presentation of an insoluble problem after experience with similar problems that were soluble. Pavlov believed that a disruption of normal excitation and inhibition in the brain accounted for experimental neurosis.

External inhibition Suppression of a CR produced by the introduction of a stimulus that produces a competing response. For example, conditioned salivation by a dog may be disrupted if the dog's name is suddenly called in a loud voice.

Extinction The decrease and eventual disappearance of a CR, which happens when the CS is repeatedly presented without a UCS. Pavlov believed that extinction brought about the inhibition of the CR.

Eyelid (eye-blink) conditioning Classical conditioning method popular in the United States. A UCS air puff to the cornea produces a UCR eye blink. A CS (such as a tone) preceding the air puff produces a CR eye blink. It is less messy than conditioned salivation, and it has been extended to the blink of the nictitating membrane in rabbits.

Final common path Sherrington's term for the motor path in the spinal reflex system. There are a great many more afferent (sensory) nerves than there are motor outlets, and he described a competition among sensory nerves for the motor outlet, or final common path.

Induction See Pavlovian induction.

Inhibition Basic neural process which Pavlov believed worked with excitation to regulate the workings of the brain. For Pavlov, inhibition meant the suppression of neural activity, directly opposing the activation produced by excitation. It is now known that excitation and inhibition are characteristics of neural activity.

Inhibition of delay A decrease in responding that occurs during the early part of the delay period during delayed conditioning. Pavlov believed that this was due to the fact that time acted as a CS, and, since the time just after the onset of the CS was never accompanied by the UCS, it became inhibitory. A handclap could restore responding during this period, showing the disinhibition of inhibition of delay.

Inhibitory conditioning Classical conditioning procedure in which a CS reliably signals the absence of a UCS. This is the opposite of excitatory conditioning.

Instrumental conditioning Learning that depends on the consequences of responses. The procedure is similar in some respects to classical conditioning. Instrumental learning is also known as operant learning.

Integrative action Sherrington's term for the coordinated activities of individual organs, with the spinal cord acting as an organ of integration. The integrative action approach studies the workings of the system as a whole and opposes the analysis of discrete units (for example, reflexes).

Interoceptive conditioning Classical conditioning in which the CS, the UCS, or both are applied within the body, to an organ or a system within the body.

Irradiation Spread of excitation and inhibition, which Pavlov supposed to occur on the surface of the cortex. During the formation of a differentiation, irradiation occurs early and late in training.

Neural unit Basic element of sensory experience first proposed by Mach in the last century and adopted by a host of workers in sensory physiology during this century. The neural unit consists of an excitatory center surrounded by a zone of inhibition.

Omission procedures Experimental procedure in which a CS is presented and a UCS thereafter, unless a CR occurred to the CS. Thus, the sight of water might be followed by a drink of water, as long as no salivation occurred when the sight of water appeared. Omission training was first used to determine whether some CRs are affected by their consequences. If a CR occurs whether it prevents a UCS or not then it is a true CR.

Paradoxical phase Stage occurring during prolonged extinction in which weak CSs produce stronger responses than do strong CSs.

Pavlovian induction Effects produced by a CS on responding during a subsequent CS. For example, positive induction occurs when a CS − precedes a CS + and the response to the CS + is stronger than when CS − does not precede it. Negative induction occurs when responding to a CS − is suppressed by an immediately preceding CS +. Pavlov believed that induction worked together with irradiation and concentration during discrimination learning.

Pseudoconditioning Apparent CRs produced because the UCS has rendered the subject overly reactive to stimuli in general. This occurs especially with strong, noxious stimuli, such as strong electric shock. Thus, if the CR is a change in heart rate and the UCS is powerful shock, a variety of stimuli other than the CS may produce heart rate change, and responses that occur to the CS therefore cannot be certified as true CRs.

Psychosomatic illness Term referring to bodily illness produced by the mind. Psychosomatic illnesses may be as fatal as other illnesses and are almost surely due to classical conditioning, at least in large part. Because the distinction between mind and body is of questionable worth, the term psychosomatic may be obsolete.

Reciprocal inhibition Term used by Sherrington to refer to the inhibition of an antagonist muscle by a contracting muscle. When the biceps contracts, the triceps is inhibited.

Reflex A reaction produced by specific stimulation. One example of an innate reflex is the constriction of the pupil produced by light in the eye.

Sensitization CRs that depend upon factors other than the specific pairings of CS and UCS. For example, a CS light could evoke eye blink responses independent of the UCS air puff. Additionally, the occasional presentation of air puffs could make such blinks more likely.

Sensory preconditioning Procedure in which two stimuli are presented together and one of them is later paired with a UCS. If the other stimulus also produces a CR, sensory preconditioning has occurred. For example, a light and a tone may be paired a number of times, followed by the pairing of the tone with electric shock. If the presentation of the light produced a shock response, then sensory preconditioning took place.

Sherrington English physiologist who won the Nobel Prize in 1932 for his earlier analysis of the spinal nervous system in 1906. Sherrington is credited with firmly establishing the reflex as the basic unit of physiology, but he chose to emphasize the workings of the nervous system as a whole, calling the reflex "a convenient fiction."

Simultaneous conditioning Classical conditioning procedure in which the CS slightly precedes and overlaps the UCS. They occur almost simultaneously; however, the CS must precede the UCS slightly. (To researchers in the U.S., however, simultaneous conditioning means that the CS and the UCS occur at exactly the same time.)

Simultaneous induction Name given by Sherrington to the fact that the stimulation of a sensory surface may produce a decrease in threshold in adjacent units which would lead to the same response. It was this usage which Skinner later meant when he referred to induction as generalization.

Spontaneous recovery Name given to the reappearance of a CR that had been extinguished earlier. Since the effect occurred only after a period of time had passed since extinction, Pavlov suggested that this was evidence for the accumulation of inhibition during extinction and its dissipation thereafter.

Successive induction Term used by Sherrington to describe the increased responsiveness of a muscle group following release from inhibition. For example, if we flex our biceps strongly for a time and then relax it, we may find our arm straightening more quickly than we expected, due to the strong contraction of the triceps. This is the sense in which Pavlov used "induction," that is, as a successive effect, of "opposite sign." Thus, excitation produces subsequent inhibition and inhibition leads to later excitation.

Trace conditioning Classical conditioning procedure in which a CS is presented, taken away, and later followed by the UCS. CRs that appear are assumed to be caused by a connection between a memory trace of the CS and the UCS.

Truly random control Procedure suggested by Rescorla in 1967 as the only appropriate control procedure for classical conditioning. This procedure also assumes a definition of conditioning as a contingent relation between the CS and the UCS; the CS must act as a reliable predictor. The control procedure defines the absence of classical conditioning by presenting the CS and the UCS randomly, so that occurrence of the CS may mean that the UCS is coming or that it is not; the CS predicts nothing.

Ultraparadoxical phase The stage of prolonged extinction in which positive CSs produce no reactions and negative CSs do produce CRs.

Unconditioned reflex Reflex behaviors that do not depend on the conditions of our experience. Unconditioned reflexes are those reactive behaviors with which we are born.

RECOMMENDED READINGS

Gray, J. A. (1979) *Ivan Pavlov*. New York: Penguin.

This is an excellent book with an accurate rendition of Pavlov's theory of brain function and related research.

Mackintosh, N. J. (1983) *Conditioning and associative learning*. New York: Oxford University Press.

This is an authoritative account of contemporary research in classical conditioning by Western researchers. However, it is not a book of light reading for beginners.

Pavlov, I. P. (1955) *Selected works*. Moscow: Foreign Languages Publishing House.

This is an interesting collection of papers, presentations, and lectures by Pavlov. His opinions on a wide variety of topics are included.

Rescorla, R. A. (1988). Pavlovian conditioning: It's not what you think it is. *American Psychologist*, *43*, 151–160.

A leading authority on classical conditioning shows how recent data have changed our interpretation of conditioning.

Swazey, J. P. (1969) *Reflexes and motor integration: Sherrington's concept of integrative action*. Cambridge: Harvard University Press.

This biography of Sherrington concentrates on his research that led to his famous Silliman lectures at Yale. The author provides an excellent presentation of the concept of integrative action, as seen by Sherrington.

Turkkan, J. S. (1989). Classical conditioning: The new hegemony. *Behavioral and Brain Sciences*, *12*, 121–179.

This survey of contemporary work in medicine, learning in simple nervous systems, learning in protozoa, physiology, and cognition shows that classical conditioning is more popular than it has been for decades. The author answers her critics, whose commentaries are included.