4

Pavlovian Conditioning

Basic Concepts

Did you know that

- classical or Pavlovian conditioning is not limited to glandular and visceral responses?
- the conditioned response is not always like the unconditioned response?
- conditioned stimuli become part of the behavior system activated by the unconditioned stimulus?
- conditioning not only results in new responses to the conditioned stimulus but also changes how organisms interact with the unconditioned stimulus?
- which stimulus can serve as a conditioned stimulus in classical conditioning depends on the unconditioned stimulus that is used?
- Pavlovian conditioning is involved in a wide range of behaviors, including preferences and aversions, fears and phobias, drug tolerance and addiction, and maternal and sexual behavior?

In Chapter 3, we described ways in which behavior is changed by experience with individual stimuli. Habituation requires presenting the same stimulus over and over again and is sometimes referred to as single-stimulus learning. We are now ready to consider how organisms learn to put things together—how they learn to associate one event with another. **Associative learning** is

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when one event (a stimulus or a response) becomes linked to another, so that the first event activates a representation of the second. It is different from single-stimulus learning in that the change in behavior that develops to one stimulus depends on when that stimulus previously occurred in relation to a second stimulus. Associative learning involves learning to connect stimuli. The first form of associative learning that we consider is Pavlovian or classical conditioning.

PAVLOV'S PROVERBIAL BELL

The basic elements of Pavlovian or classical conditioning are familiar to most people. Accounts usually describe an apocryphal experiment in which Professor Ivan Pavlov rang a bell just before giving a bit of food powder to the dogs that he was testing. The dogs were loosely harnessed and hooked up to an apparatus that enabled Pavlov to measure how much they salivated. At first the dogs salivated only when they were given the food powder. However, after several trials of the bell being paired with the food, the dogs also came to salivate when the bell sounded. In this scenario, the food powder that elicits salivation without prior training is called the **unconditioned stimulus**, or **US**. The salivation elicited by the food powder is called the **unconditioned response**, or **UR**. The bell is called the **conditioned stimulus**, or **CS**, and the salivation that develops to the bell is called the **conditioned response**, or **CR**. The US that elicits a UR is an unconditioned reflex, whereas a CS that elicits a CR is a conditioned reflex.

The story of Pavlov ringing a bell does not describe an actual experiment that Pavlov conducted and is misleading in several respects. Pavlov did not use a bell in his experiments. The initial experiments on salivary conditioning were conducted by two of Pavlov's research associates, Vul'fson and Snarskii, who tested the effectiveness of various substances (e.g., dry food, sour water, or sand) placed in the dog's mouth in eliciting salivation (Todes, 1997). These substances elicited salivation unconditionally the first time they were given to the dog. With repeated testing, the dogs also came to salivate at the sight of these substances before they were placed in the mouth. Thus, in these experiments, the CS was a visual cue. Furthermore, the visual CS was not an arbitrary stimulus unrelated to the US. Rather, the CS was a feature of the object that was used as US. Thus, the initial experiments on Pavlovian conditioning involved **object learning**, a form of learning in which different features of an object become associated with one another. In later experiments, a variety of conditioned stimuli were used, including the clicking sound of a metronome and vibrotactile stimuli applied to the skin. Interestingly, Pavlov saw little difference in the ability of these various stimuli to serve as a CS. They all came to provoke a salivary CR when paired with the food US.

The first 50 years of the 20th century did not see much progress in the study of Pavlovian conditioning beyond the work of Pavlov, and not everyone was impressed. In particular, Skinner (1953) considered Pavlovian conditioning to be limited to physiological reflexes and of little relevance to forms of learning that involve manipulations of the environment rather than just reactions it. Skinner's attitude about Pavlovian conditioning had a major influence on how Pavlovian conditioning was treated in applied behavior analysis (J. O. Cooper et al., 2020). However, such a limited perspective is no longer tenable (Urcelay & Domjan, 2022). Pavlov clearly did not have the last word.

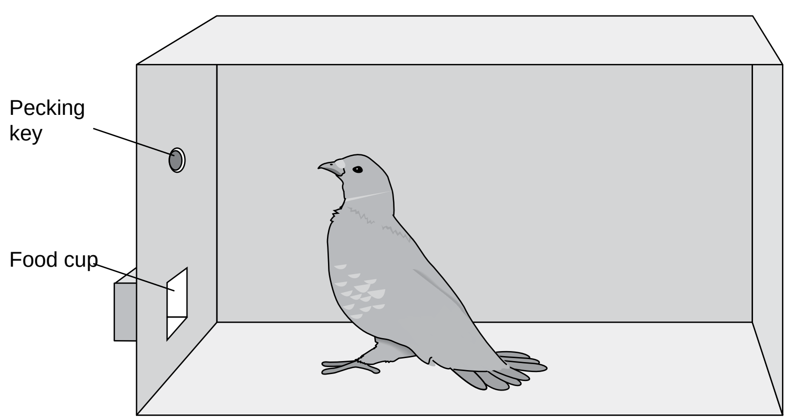
CONTEMPORARY CONDITIONING SITUATIONS

Although classical conditioning was discovered in studies of salivary conditioning with dogs, dogs generally do not serve as research participants in contemporary Pavlovian conditioning research, and salivation is rarely the response that is conditioned. Instead, experiments on Pavlovian conditioning are conducted with pigeons, mice and rats, rabbits, and human participants, and the CR that is of interest is often a skeletal rather than glandular or physiological response. One type of Pavlovian conditioning is **appetitive conditioning**, in which the US or reinforcer is a desirable or appetitive stimulus like food. Another type is **aversive conditioning**, also known as **fear conditioning**, in which an unpleasant or aversive event is used as the US.

Appetitive Conditioning

Appetitive conditioning is frequently investigated with pigeons and laboratory rats. Pigeons that serve in appetitive conditioning experiments are mildly hungry and are tested in a small experimental chamber (see Figure 4.1). The CS is a circular spot of light projected onto a small plastic disk or touch screen

FIGURE 4.1. Typical Trial for Conditioning Sign Tracking or Autoshaping in Pigeons



Note. The conditioned stimulus (CS) is illumination of a small circular disk or pecking key for 6 seconds. The unconditioned stimulus (US) is access to food for 4 seconds. CS–US trials are repeated, with an intertrial interval of about 1 minute.

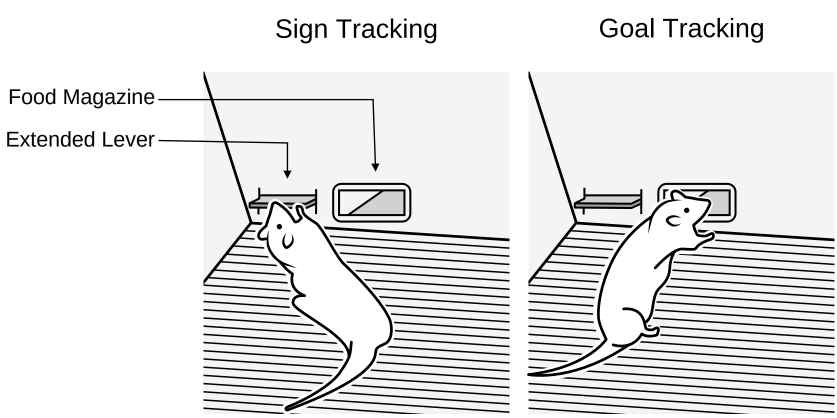
above a food cup. Pecks at the light are automatically detected. The conditioning procedure consists of turning on the key light for a few seconds and then presenting a small amount of food. No response on the part of the pigeon is required for the food to be delivered after the light.

After several pairings of the key light with food, the pigeons come to approach and peck the key when it is lit (Hearst & Jenkins, 1974; Tomie et al., 1989). The conditioned approach and pecking behavior develop even if the key light is located some distance from the food cup (Boakes, 1979). The light becomes a signal for food, and the pigeons go where the light is located. This type of conditioned responding is called **sign tracking**, elicited behavior directed toward a stimulus that is reliably paired with a primary reinforcer. Because the procedure results in the pigeons pecking the response key without being required to do so and without shaping by the experimenter, sign tracking was originally called **autoshaping**.

Sign tracking has also been extensively investigated with laboratory rats. In these experiments, a pellet of food is delivered into a food cup as the US. A response lever is located on one side of the food cup (see Figure 4.2). Ordinarily the lever is retracted and is unavailable to the rat. A few seconds before each delivery of food, the response lever is illuminated and extended into the chamber. This event (light + lever) serves as the CS and comes to signal the impending delivery of food. As in the pigeon experiments, the rats do not have to do anything to receive the food pellet. Nevertheless, they make anticipatory CRs before the food is delivered on each trial.

Some of the rats show conditioned sign tracking and approach, touch, and manipulate the response lever when it is lit and inserted into the chamber. Other rats approach the food cup when they get the CS. When a conditional

FIGURE 4.2. Illustration of Sign Tracking and Goal Tracking in Laboratory Rats



Note. The conditioned stimulus (CS) is the extension of an illuminated response lever into the experimental chamber at the start of a conditioning trial. The unconditioned stimulus (US) is presentation of a pellet of food. With these procedures, about one third of the rats show sign tracking, one third show goal tracking, and the rest show a combination of the two responses (Flagel et al., 2009).

response is directed toward the location of reward delivery (i.e., the goal) rather than the signal for reward, the behavior is called **goal tracking**, or **magazine conditioning**. A food magazine is a mechanism that delivers the reinforcer into a food cup. The remaining rats show a combination of sign tracking and goal tracking before the food is delivered. About a third of the rats fall into each of these categories (Flagel et al., 2009; Meyer et al., 2012). Thus, the rats show systematic individual differences in what type of conditioned behavior they engage in as a result of the appetitive conditioning procedure.

Individual differences in sign tracking versus goal tracking have attracted a great deal of interest. Such individual differences challenge the simple notion that CS–US pairings result in a predictable and uniform CR. This has encouraged investigators to propose new learning theories that for the first time address individual differences in the type of conditioned behavior that develops with a given conditioning procedure. One major proposal is that the nature of the CR depends on the relative salience of the mental representations of the CS and the US. Greater salience of the mental representation of the CS leads to sign tracking, whereas greater mental representation of the US leads to goal tracking (Honey et al., 2020).

Another major proposal is that sign tracking versus goal tracking reflects individual differences in the propensity to acquire incentive motivation. Incentive motivation plays a major role in addictions, where exposure to signals for the drug of choice makes the procurement of an appetitive reinforcer irresistible. Individuals addicted to alcohol, for example, find the urge to drink irresistible when they see or smell an alcoholic drink. For them, the sight and smell of alcohol has become a strong incentive stimulus. Responses to the sight and smell of alcohol are sign tracking CRs (Zito & Tomie, 2014). It is of additional interest that sign-tracking rats display exaggerated sensitization to cocaine administration (Flagel et al., 2008) and to cues signaling cocaine (Yager & Robinson, 2013) compared with goal-tracking rats.

In addition to the relation of sign tracking to drug addiction, research has indicated that a propensity to show sign tracking is also related to attentional deficits, novelty seeking, risk taking, and impulsivity (Colaizzi et al., 2020). Although most of this research was conducted with laboratory rats, these issues are also starting to be explored in humans as well (Colaizzi et al., 2023).

Aversive or Fear Conditioning

Aversive conditioning has been extensively investigated using the eyeblink response. The eyeblink is an early component of the startle reflex. Eyeblink conditioning was first developed with human participants (see Kimble, 1961, pp. 55–59). A mild puff of air to one eye served as the US, and a light served as the CS. After multiple pairings of the light with the air puff, the light came to elicit a conditioned eyeblink response. Subsequently, techniques for studying eyeblink conditioning were also developed for use with albino rabbits and laboratory rats, to facilitate investigations of the neurophysiology of learning. With these species, irritation of the skin near one eye serves as the US, and a brief visual or auditory cue serves as the CS. Pairings of the CS and US result in a conditioned eyeblink response when the CS is presented (Gormezano et al., 1983).

A great deal of research has been done on the neurobiology of eyeblink conditioning (Thompson, 2005). Various aspects of eyeblink conditioning are mediated by neural circuits involving the cerebellum, the hippocampus, and the amygdala, areas that have been also implicated in various clinical disorders. For example, considerable evidence from behavioral and neurobiological studies indicates that there is a strong relationship between the rate of eyeblink conditioning and posttraumatic stress disorder (Allen et al., 2019).

Another common laboratory technique for studies of aversive conditioning is fear conditioning. This procedure, typically carried out with rats or mice, takes advantage of the fact that animals (including people) tend to be come motionless, or freeze, when they are afraid. A tone or light serves as the CS, and a brief shock applied through a grid floor serves as the US. After a few pairings of the tone or light with the shock, the CS comes to elicit a freezing response. In the freezing posture, the rat exhibits total lack of movement except for breathing (N. S. Jacobs et al., 2010).

Fear conditioning procedures have also been developed for experiments with human participants. Visual cues presented on a computer screen are typically used as the CS, and mild shock applied to a finger, wrist, or shin serves as the US. Fear is measured using physiological indices (e.g., a change in skin conductance), as well as self-reports of shock expectancy and ratings of how much the participant has come to dislike the CS (Lonsdorf et al., 2017). Interestingly, conditioned fear responses in humans can be dissociated from explicit shock expectations, suggesting that the CR in these situations can reflect a basic learning process that may be distinct from conscious awareness (e.g., Perruchet, 2015). Investigators of conditioned fear in human participants are also starting to identify a connection between the generalization of conditioned fear and anxiety-related disorders (S. E. Cooper et al., 2022).

THE NATURE OF THE CONDITIONED RESPONSE

In Pavlov's salivary conditioning experiments, the CR (salivation to a CS) was a glandular visceral response similar in form to the UR (salivation to food). This encouraged two generalizations—namely, that Pavlovian conditioning only altered glandular responses (Skinner, 1953) and that the CR is always similar to the UR (e.g., Mackintosh, 1974). However, neither of these assumptions are valid for the laboratory situations that are commonly used in contemporary research on Pavlovian conditioning.

Sign tracking, goal tracking, and conditioned eyeblink responses are skeletal rather than glandular responses. In eyeblink conditioning, the CR is similar to the UR. However, this is not true in many other conditioning situations. In fear conditioning, for example, the foot shock that serves as the US elicits a vigorous startle and jump response, but the CS comes to elicit a contrasting freezing response. In many Pavlovian situations, the CR is not similar to the responses that are elicited by the US. In sign tracking, the food US elicits approach to the food cup, but if the CS is located away from the food cup, the CS elicits movement away from the food cup and towards the CS.

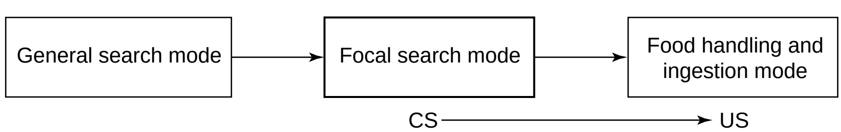
If we cannot assume that the CR will always be similar to the UR, how can we predict what kind of behavior will develop with Pavlovian conditioning? This remains a challenging question. A promising approach to answering the questions is based on the identification of preexisting behavior systems that may be activated by a Pavlovian conditioning procedure.

We previously introduced the concept of behavior systems in Chapter 2. The concept is relevant to the present discussion because the US in a Pavlovian conditioning procedure activates the behavior system relevant to that US. Presentations of food to a hungry animal activate the feeding system, presentations of shock activate the defensive behavior system, and presentations of a sexual US activate the reproductive behavior system. The CR that develops depends on how the CS becomes incorporated into the behavior system activated by the US (Domjan & Krause, 2017).

As we discussed in Chapter 2, the feeding system involves a sequence of response modes starting with general search and then moving on to focal search and ingestive or consummatory behavior (see Figure 4.3). If a CS is presented before the animal receives each portion of food, the CS will become incorporated into one of the response modes of the feeding behavior system, which will in turn determine what type of CR the organism will perform (Timberlake, 2001). If the CS becomes incorporated into the focal search mode, the CR will consist of focal search responses such as sign tracking or goal tracking (Wasserman et al., 1974). In contrast, if the CS becomes incorporated into the ingestive, consummatory response mode, the CR will involve handling and chewing the CS (Boakes et al., 1978).

In aversive conditioning, the nature of the CR is determined by the defensive behavior system (Fanselow et al., 2019). In studies of fear conditioning with laboratory rats and mice, the foot shock US is an external source of pain, much like being bitten by a predator, and the response to shock is similar to the response to being bitten. When a rat is bitten by a snake, it leaps into the air. Similarly, rats jump when they receive a brief foot shock. The rat's defensive response to an impending or possible attack is different from its response

FIGURE 4.3. Behavior Systems and Pavlovian Conditioning



Note. Conditioning procedures with food as the unconditioned stimulus (US) involve the feeding system. As a result of pairings of the conditioned stimulus (CS) with food, the CS becomes incorporated into the feeding system and comes to elicit food-related responses.

to the attack itself. If a rat sees or smells a snake that is about to strike, the rat freezes. In the fear conditioning procedure, the CS signals an impending attack. Therefore, the CS comes to elicit the freezing defensive behavior.

Because the CS usually precedes the presentation of a US in a Pavlovian conditioning procedure, responses to the CS are anticipatory responses. What kind of anticipation is appropriate depends on how long you have to wait during the CS before the US occurs. Therefore, the interval between the onset of the CS and the onset of the US is critical in determining the nature of the CR. In aversive conditioning, for example, a long CS–US interval results in conditioned anxiety, whereas a short CS–US interval results in conditioned fear or panic (Waddell et al., 2006). In sexual conditioning, a long CS–US interval activates the general search mode in which there is an increase in general locomotor behavior. In contrast, a short CS–US interval activates the focal search model, which results in sign tracking behavior (Akins, 2000).

CONDITIONED MODIFICATIONS OF THE UNCONDITIONED RESPONSE

In the preceding discussion, we followed the common practice of talking about Pavlovian conditioning as learning to anticipate a biologically significant event, the US. Why should organisms respond in anticipation of something? What is the advantage of anticipation? The value of anticipating a significant event is that you can deal with that event more effectively when it arrives. This suggests that Pavlovian conditioning should also change how organisms interact with the US. That is, in fact, the case. There is a large body of evidence now indicating that presentation of a CS alters how organisms interact with the US.

One of the first areas of research in which Pavlovian conditioning was found to change how organisms interact with the US is drug conditioning. When we take a drug for either recreational or therapeutic reasons, we focus on the pharmacological or unconditioned effects of the drug. However, there is also a strong conditioning component because drugs are typically administered using a ritual of some sort. The pharmacological effects of caffeine or a glass of wine, for example, are preceded by the smell and taste of the coffee or wine, as well as the particular place or time of day when the drugs are ingested. Smell, taste, and other cues related to drug administration function as conditioned stimuli that become associated with the unconditioned pharmacological effects of caffeine and alcohol.

Drugs are disruptive to normal physiological functioning or physiological homeostasis. With repeated administrations of a drug, the body comes to anticipate these disruptive effects and learns to make compensatory adjustments in anticipation of the drug. The anticipatory adjustments are elicited by drug-conditioned cues and serve to attenuate the impact of the drug once it is ingested. Through this process, the impact of the drug is gradually reduced, an outcome known as **drug tolerance**, a condition resulting from repeated use of a drug, characterized by a markedly diminished effect with regular use of the same dose of the drug or by a need to increase the dose markedly over time to achieve the same desired effect.

An important implication of these learning mechanisms is that tolerance to a drug can be reversed if the drug is taken in a new place or in the absence of the usual drug-administration cues. Extensive research has confirmed this prediction as well as numerous other implications of the conditioning model of drug tolerance (S. Siegel, 2008). One unfortunate consequence of the reversal of drug tolerance is that familiar doses of a drug that previously were not lethal become life-threatening if the drug is taken in the absence of the usual drug-administration cues (S. Siegel, 2016).

The conditioning model of drug tolerance is not only of clinical significance. It also supports the idea that Pavlovian conditioning serves to modify how organisms respond to the US. This new perspective has been documented in a variety of Pavlovian conditioning situations, including appetitive conditioning, fear conditioning, defensive conditioning, and sexual conditioning (Domjan, 2005). In the sexual conditioning of male quail, for example, a CS is paired with access to a sexually receptive female. With repeated pairings, the CS will acquire incentive motivational properties and elicit sign tracking. However, a more important result is that exposure to a sexual CS significantly changes how the male copulates with the female. The sexual CS reduces the male's latency to initiate copulation, increases courtship responses, increases the efficiency of copulatory behavior, and enhances the release of sperm and the fertilization of eggs (Domjan & Gutiérrez, 2019). All these changes in behavior represent changes in how the male interacts with the US, which in this case is a female sexual partner.

STIMULUS FACTORS IN CLASSICAL CONDITIONING

The first few generations of scientists who took up the study of Pavlovian conditioning assumed that just about any stimulus the organism could detect could be effectively used as a CS. Early behaviorists regarded organisms as being totally flexible in what they could learn. However, this assumption has turned out to be incorrect. In this section, we describe two factors that determine the effectiveness of a CS: the novelty of the CS and the nature of the US.

CS Novelty and the Latent Inhibition Effect

Novelty of a stimulus is a powerful factor determining its behavioral impact. As we saw in Chapter 3, repeated exposures to a stimulus result in a habituation effect, making highly familiar stimuli less effective in eliciting behavioral reactions than novel stimuli. Habituation can also reduce the effectiveness of a stimulus that is later used as a CS in a Pavlovian conditioning procedure. This phenomenon is called the **latent inhibition effect** (Lubow & Weiner, 2010).

Studies of the latent inhibition effect are usually conducted in two phases, the preexposure phase and the conditioning phase. In the preexposure phase, participants are given repeated presentations of the stimulus that will be used later as the CS. For example, a tone that subsequently will be paired with food may be presented multiple times by itself without food during the preexposure phase. After the preexposure phase, the tone is paired with the food US, using conventional classical conditioning procedures. The typical outcome is that CS preexposure retards the subsequent development of conditioned responding to the tone.

One major approach to explaining the CS preexposure effect has involved attentional processes (e.g., Rodríguez et al., 2019). Repeated presentations of (for example) a tone during the preexposure phase presumably reduces the participant's attention to the tone, and this in turn disrupts subsequent Pavlovian conditioning of the tone. Because of the involvement of attentional processes, the latent inhibition effect has become promising as a technique for studying brain mechanisms and disorders such as schizophrenia that involve deficits in attention (Lubow, 2011; but see also Byrom et al., 2018).

Another approach has been to consider latent inhibition from the perspective of memory interference. According to this approach, repeated presentations of a tone without a US could lead to learning that the CS occurs without any other event. The memory of such CS–no event learning then interferes with subsequent learning that the CS predicts the US during the subsequent conditioning phase (e.g., Hall & Rodriguez, 2011).

CS–US Relevance and Selective Associations

The effectiveness of a stimulus as a CS in Pavlovian conditioning also depends on the US that is employed. As we noted earlier, presentations of a US activate the behavior system relevant to that US. Thus, the feeding behavior system is activated when food is repeatedly presented to a hungry pigeon. As we discussed in Chapter 2, each behavior system is associated with its own distinctive set of responses. Behavior systems are also characterized by enhanced reactivity to a distinctive set of stimuli. Pigeons, for example, tend to locate food by sight and become highly attuned to visual cues when their feeding system is activated. This makes visual cues especially effective in Pavlovian conditioning with food for pigeons.

The first clear evidence that the effectiveness of a CS depends on the US that is employed was obtained in studies of aversion conditioning in laboratory rats. Fear conditioning illustrates one type of aversion conditioning. Here a tone or light is paired with shock, with the result that the CS comes to elicit a fear or freezing response. Another type of aversion conditioning is **taste aversion learning**. Here a novel taste is followed by postingestional illness (e.g., a mild case of food poisoning), and the individual learns an aversion to the novel taste as a result.

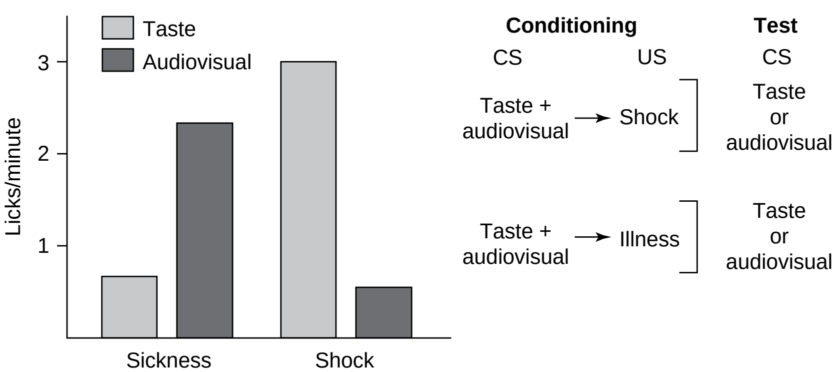
Fear conditioning and taste aversion learning demonstrate that auditory, visual, and taste cues are highly effective as conditioned stimuli. Interestingly, however, the effectiveness of these cues depends on the US that is used (see Figure 4.4). If foot shock is the US, rats readily learn an aversion to an audiovisual CS. However, rats do not easily learn an aversion to a taste CS that is paired with shock. In contrast, if illness is used as the US, rats readily learn a taste aversion but not an aversion to an audiovisual cue (Garcia & Koelling, 1966). Such results illustrate the phenomenon of **CS–US relevance**, or **selective association**, facilitated learning that occurs with certain combinations of conditioned and unconditioned stimuli.

The Garcia–Koelling selective association effect met with great skepticism when it was first reported, but much of that skepticism has been laid to rest by subsequent research. This research has confirmed the validity of the selective association effect reported by Garcia and Koelling and demonstrated that the phenomenon is not the result of sensitization artifacts (Domjan, 2015).

Like laboratory rats, people also learn aversions to stimuli selectively. People who experience gastrointestinal illness are more likely to learn an aversion to a novel food they ate just before becoming sick than they are to learn an aversion to the utensils or plate they used when eating the food. Consistent with the selective association effect, people do not report acquiring a food aversion if they hurt themselves in a physical accident or if they develop an irritating skin rash (Logue et al., 1981; Pelchat & Rozin, 1982). Only illness experiences are effective in inducing a food aversion.

Since the initial demonstration of the selective association effect in aversion learning, such effects have been found in other forms of learning as well. For example, Shapiro et al. (1980) found that pigeons are more likely to associate a visual stimulus than an auditory stimulus with food. However, when the birds are conditioned with shock, the auditory cue is more likely to become conditioned than the visual cue. Selective associations also occur in primate fear conditioning (Mineka & Öhman, 2002). Monkeys and people learn to be fearful of the sight of snakes more easily than the sight of flowers. This seems to be the result of an evolutionary predisposition. Enhanced sensitivity to the sight of snakes has been observed in human infants as young as 8 to 14 months of age

FIGURE 4.4. Procedure and Results of the Experiment by Garcia and Koelling (1966) Demonstrating Selective Associations in Aversion Learning



(LoBue & DeLoache, 2010). (For a discussion of the role of stimulus relevance effects in human learning and memory, see Seitz et al., 2019.)

THE CONTROL PROBLEM IN PAVLOVIAN CONDITIONING

The critical feature of Pavlovian conditioning is that it involves the formation of an association between a CS and an US. Therefore, before any change in behavior can be attributed to Pavlovian conditioning, one must demonstrate that the effect is not produced by other factors that do not involve a CS–US association.

To promote the development of an association, the conditioned and unconditioned stimuli have to be presented in combination with one another. It is particularly effective, for example, to present the CS just before the presentation of the US on each conditioning trial. (We will have more to say about this in Chapter 5.) In addition, multiple conditioning trials are usually needed to get a learning effect. Thus, a Pavlovian conditioning procedure involves repeated presentations of the conditioned and unconditioned stimuli. However, as we saw in Chapter 3, repeated presentations of stimuli can also result in habituation and sensitization effects. This suggests that habituation and sensitization effects can occur during the course of Pavlovian conditioning.

Habituation and sensitization effects due to repeated CS and US presentations do not depend on the formation of an association between the CS and US and therefore do not constitute Pavlovian conditioning. Habituation effects are typically of little concern because habituation results in decreased responding whereas Pavlovian conditioning involves increased responding to the CS. However, increased responding to the CS can be due to sensitization resulting from CS exposures or to dishabituation or sensitization resulting from US presentations. Control procedures have to be used to rule out such sensitization effects in studies of Pavlovian conditioning.

A universally applicable and acceptable solution to the control problem in Pavlovian conditioning has not been agreed on. Instead, a variety of control procedures have been used, each with its own advantages and disadvantages. In one procedure, CS sensitization effects are evaluated by repeatedly presenting the CS by itself. Such a procedure, called the *CS-alone control*, is inadequate because it does not take into account the possibility of increased responding to the CS due to dishabituation or sensitization effects of the US. Another control procedure involves repeatedly presenting the US by itself (the *US-alone control*) to measure US-induced sensitization. This procedure, however, does not consider possible sensitization effects due to repeated CS presentations.

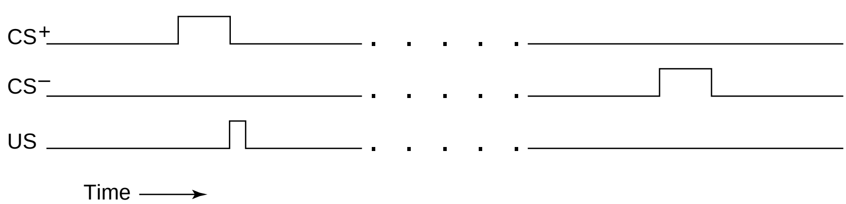
In 1967, Rescorla proposed an ingenious solution, known as the **random control** procedure, that appeared to overcome the shortcomings of the CS-alone and US-alone controls. In the random control procedure, the CS and US are both presented repeatedly, but at random times in relation to each other. The random timing of the CS and US presentations is intended to prevent the formation of an association between them without interfering with sensitization processes.

The random control procedure became popular soon after its introduction, but as investigators began to examine it in detail, they discovered some shortcomings (Papini & Bitterman, 1990). Random CS and US presentations permit occasional instances in which the CS is presented in conjunction with the US. If such occasional CS–US pairings occur early in a sequence of random CSs and USs, conditioned responding may develop (Benedict & Ayres, 1972). Another limitation is that it is difficult to implement the random control if you conduct just one conditioning trial, which is common in studies of taste aversion learning and fear conditioning. Despite these shortcomings, the rationale for the random control remains viable, and there are numerous examples of the successful use of the random control (e.g., Delamater et al., 2014; Rescorla, 2000).

Another method for controlling for associative effects is the **discriminative control** procedure. This procedure is summarized in Figure 4.5. The discriminative control involves two conditioned stimuli, a CS^+ and a CS^-. The two CSs may be, for example, a brief tone and a brief light. On half the trials, the CS^+ is presented and paired with the US, indicated by the plus (+) sign. On the remaining trials, the CS^- is presented and the US does not occur, indicated by the minus (–) sign. CS^+ and CS^- trials are alternated randomly. For half the participants, the tone serves as the CS^+ and the light serves as the CS^-; for the remaining participants, these stimulus assignments are reversed.

What would happen if presentations of the US only sensitized responding to the light and tone CSs? Sensitization is not based on an association and thus does not depend on the pairing of a stimulus with the US. Therefore, sensitization is expected to elevate responding to both the CS^+ and the CS^-. In contrast to sensitization, associative learning should be specific to the stimulus that is paired with the US. Therefore, associative learning should elevate responding to the CS^+ more than the CS^-. Greater responding to the CS^+ than to the CS^- in the discriminative control provides good evidence of associative learning.

FIGURE 4.5. Diagram of the Discriminative Control Procedure for Pavlovian Conditioning



Note. Two types of trials occur in random alternation. On some trials, one conditioned stimulus, the CS^+, is paired with the unconditioned stimulus (US). On the remaining trials, another conditioned stimulus, the CS^-, is presented alone. Stronger conditioned responding to CS^+ than to CS^- is evidence of associative learning rather than some form of sensitization.

The discriminative control procedure permits the evaluation of associative effects within a single group of participants (based on how those participants respond differently to the CS^+ vs. the CS^-). Another approach that is frequently employed is the **unpaired control procedure**. In this procedure, the CS and US are presented repeatedly, but the stimulus presentations are deliberately scheduled so that the CS and US never occur together or on the same trial. This procedure is administered to a control group, which is compared with an experimental group that receives the CS paired with the US. Greater responding in the paired group compared with the unpaired group is considered evidence that pairings are important for associative learning.

PREVALENCE OF PAVLOVIAN CONDITIONING

The prevalence of Pavlovian conditioning is not obvious if we think of conditioned stimuli as "arbitrary" or "neutral" cues that are paired with an US. If a CS is "arbitrary" or "neutral," how does it get paired with a US consistently in the natural environment? This puzzle is easily resolved if we realize that in the natural environment, conditioned stimuli are not "arbitrary" or "neutral" but are natural precursors or antecedents to unconditioned stimuli. Food, for example, never magically appears in our mouth. Rather, we have to procure, handle, and put the food in our mouth. Those antecedent activities provide conditioned stimuli that inevitably precede the food US.

The idea that conditioned stimuli are natural precursors experienced before contact with an US was illustrated by the original experiment on salivary conditioning conducted by Pavlov's associates Vul'fson and Snarskii. As we noted earlier in this chapter, they conditioned salivation to the visual features of the substances that they used to elicit salivation unconditionally. Their experiments illustrated how one aspect of an object (e.g., the visual feature of food) can become associated with other features (e.g., food in the mouth) that function as unconditioned stimuli. We referred to this as *object leaning*.

Our daily lives involve interacting with lots of different objects. Objects inevitably have multiple features (e.g., color, shape, taste, smell). Some of those features may elicit behavior unconditionally. The unconditioned features in turn lead to learning about other aspects of the objects that become associated with the unconditioned features. For example, an infant suckling initially responds just to the nipple that provides milk. However, with repeated suckling experiences, the infant comes to associate olfactory and tactile cues provided by the mother with the nursing experience (Blass et al., 1984; Delaunay-El Allam et al., 2010).

Object learning reflects the spatial organization of stimuli in our environment. The multiple stimulus features of an object are located close to each other in space. Events in our environment are also temporally organized. Most of the stimuli we encounter occur in an orderly temporal sequence because of the physical constraints of causation. Some things simply cannot happen before other things have occurred. Social institutions and customs also make sure that events occur in a reliable temporal sequence. We don't talk to someone until we first face, approach, and greet them. Whenever one stimulus reliably precedes another, classical conditioning may take place. Through classical conditioning, you come to predict what will happen next based on antecedent events that serve as conditioned stimuli.

The temporal organization of events is a prominent feature of drug self-administration. Someone having a beer cannot feel the pharmacological effects of the alcohol before first smelling and tasting the beer. People who use recreational drugs typically have a ritual for how they take them. The sensory aspects of those rituals always precede the physiological impact of the drug (which serves as the US). This allows the drug administration cues to serve as conditioned stimuli that come to elicit drug anticipatory CRs (S. Siegel, 2008, 2016).

The temporal organization of events is also a prominent feature of sexual or copulatory behavior. Sexual activity is not possible unless one has located and approached the potential sexual partner. This allows the cues involved in identifying a sexual partner to become associated with sexual activity (Domjan & Gutiérrez, 2019).

Temporal organization is also prominent with aversive encounters. One cannot suffer a car accident without first riding in a car. An abusive parent cannot scream at a child until the parent has returned home, and a hawk is not likely to pounce on a mouse until the mouse has come out of hiding. Unconditioned stimuli are usually "announced" by antecedent events that can then serve as conditioned stimuli. This makes Pavlovian conditioning a pervasive feature of our experience.

SUMMARY

Although studies of Pavlovian conditioning began with the conditioning of salivation and other glandular responses in dogs, contemporary investigations frequently involve skeletal responses, as in sign tracking, goal tracking, eyeblink, and fear conditioning. These investigations have shown that a variety of CRs can develop, depending on the nature of the CS and the behavior system activated by the US.

Because Pavlovian conditioning involves the learning of an association between a CS and a US, behavioral changes due to mere repetition of the CS and US have to be ruled out. No universally satisfactory control procedure is available for Pavlovian conditioning. Rather, investigators typically use one of three strategies. In the random control, CS and US presentations occur at random times independently of each other. In the discriminative control procedure, one CS is paired with the US, and another CS is presented without the US. Differential responding to the two CSs provides evidence of associative learning. In the unpaired control procedure, the CS is presented at times when the US is certain not to occur.

Pavlovian conditioning readily occurs outside the laboratory. One common source of natural learning is object learning, where one feature of an object (the CS) becomes associated with other features (the US). Pavlovian conditioning in natural environments is also common because stimuli in the natural environment do not occur at random but are arranged sequentially in space and time. Pavlovian conditioning takes advantage of that spatial and temporal organization and enables us to use some stimuli (CSs) to predict other events that will happen (USs). Because of this, Pavlovian conditioning is involved in virtually everything we do, ranging from finding food and eating and drinking, to caring for our young, to learning what may cause injury, to finding mates and engaging in sexual behavior, and even to consuming psychoactive drugs.

SUGGESTED READINGS

Allen, M. T., Handy, J. D., Miller, D. P., & Servatius, R. J. (2019). Avoidance learning and classical eyeblink conditioning as model systems to explore a learning diathesis model of PTSD. *Neuroscience and Biobehavioral Reviews*, *100*, 370–386. https://doi.org/10.1016/j.neubiorev.2019.03.003

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TECHNICAL TERMS

associative learning, page 45
unconditioned stimulus (US), page 46
unconditioned response (UR), page 46
conditioned stimulus (CS), page 46
conditioned response (CR), page 46
object learning, page 46
appetitive conditioning, page 47
aversive conditioning, page 47
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sign tracking, page 48
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For chapter summaries and practice quizzes, visit https://www.apa.org/pubs/books/essentials-conditioning-learning-fifth-edition (see the Student Resources tab).