Handbook of Applied Behavior Analysis

Edited by

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CHAPTER 2

Respondent (Pavlovian) Conditioning

John W. Donahoe and Rocío Vegas

At the dawn of the previous century, two scientists—one in St. Petersburg, Russia, and the other in Cambridge, Massachusetts—independently began their search to discover how the environment produces long-lasting changes in behavior. The first scientist was Ivan Pavlov (1927/1960), a physiologist whose earlier research on digestion would ultimately earn a Nobel Prize. The second was Edward Thorndike (1903), a psychologist whose later published work would ultimately exceed that of any other psychologist—past or present (Jonçich, 1968). The methods used by these pioneers differed, but both described themselves as following in Darwin's footsteps: They were attempting to explain complex phenomena as the cumulative product of simpler, more basic processes. For Darwin, the basic process had been natural selection. For Pavlov and Thorndike, the basic process became known as selection by reinforcement. Darwin studied how changes in *structure* could arise from natural selection. Pavlov and Thorndike studied how changes in *function* could arise from *selection by reinforcement*. All shared the hope that even the most complex phenomena could be explained by relatively simple selection processes acting over time. The selection process discovered by Darwin acted over extremely long periods of time and could be known largely through naturalistic observation. Selection by reinforcement occurred rapidly, however, and could be studied with the powerful procedures available in the laboratory.

Pavlov's and Thorndike's procedures differed in a critically important respect but began from the same starting point—by presenting a stimulus to which the learner would already respond. Both Pavlov and Thorndike presented an *eliciting stimulus*, food, that evoked consummatory behavior. Primarily because of natural selection, the taste, smell, and sight of food elicited a variety of responses—including salivation and approach. Moreover, these stimuli could be readily manipulated, and the responses they elicited could be measured. Where Pavlov and Thorndike differed was in regard to the type of event that reliably preceded the food. In Pavlov's procedure, food was contingent on the prior occurrence of a specified *stimulus*, for example, the "ticking" sound of a metronome. In Thorndike's procedure, food was contingent on the prior occurrence of a specified *behavior*; for example, escape from a cage (or a "puzzle box," as it was called).

The differences and similarities between Pavlov's and Thorndike's procedures are illustrated in Figure 2.1.

As shown in Figure 2.1, the central difference between the procedures is that a specific environment (E_i) reliably precedes the eliciting stimulus in Pavlov's procedure, whereas a specific behavior (B_j) reliably precedes the eliciting stimulus in Thorndike's procedure. Pavlov devised a technical vocabulary for the stimulus and response events in his procedure. The environmental event that preceded the *elicitation process* (a term that designates the eliciting stimulus together with its elicited response) is called the *conditioned stimulus* (CS). The eliciting stimulus is the *unconditioned stimulus* (US), and the elicited response is the *unconditioned response* (UR). In Pavlov's laboratory, the CS might be presentation of the ticking sound of a metronome, the US, presentation of food; and the UR, elicitation of salivation. After several pairings of the CS with the US/UR, the CS evoked a response that, in the typical case, resembled the UR. The response that came to be evoked by the CS was called the *conditioned response* (CR) and is the behavioral change usually monitored in a Pavlovian procedure. In the Pavlovian example illustrated in Figure 2.1, measures of the salivary response serve as the UR and CR. The process whereby the environment acquires its ability to control behavior is called *conditioning* because the ability of the CS to evoke the CR was *conditional* on (i.e., dependent on) pairing the CS with the US/UR. Pavlov's procedure is most often called *classical conditioning* in recognition of his historical priority. Following Pavlov's lead, the outcome of Thorndike's procedure has also come to be called conditioning—but *operant* or *instrumental conditioning* to distinguish it from the procedure used in classical conditioning. However, as already noted, Thorndike's procedure differed from Pavlov's in a critical respect: The event that reliably preceded the elicitation process was a *response*, not a stimulus. Because behavioral change in both procedures is dependent on the presentation of an eliciting stimulus, the eliciting stimulus is called a *reinforcing stimulus*, or simply a *reinforcer*.

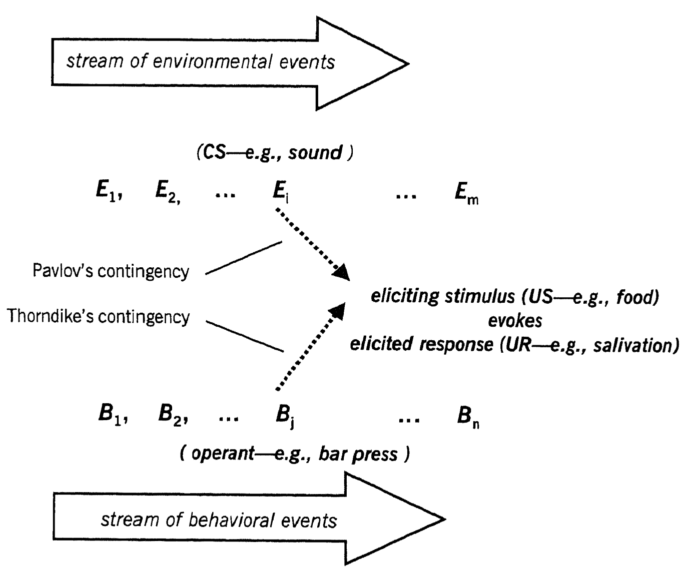

FIGURE 2.1. The critical events in Pavlov's and Thorndike's procedures. In both procedures, the learner is immersed in a stream of environmental (E) events and is continuously behaving (B) in their presence. The experimenter introduces an eliciting stimulus into the environment in both procedures. The critical difference between the two procedures is that in Pavlov's procedure an environmental stimulus (here, E_i) reliably precedes the eliciting stimulus, whereas in Thorndike's procedure a specific behavior (here, B_j) reliably precedes the eliciting stimulus. The technical term for the environmental event that precedes the eliciting stimulus is the conditioned stimulus (CS), for the eliciting stimulus is the unconditioned stimulus (US, which functions as a reinforcer), and for the elicited response is the unconditioned response (UR).

Skinner's View of the Difference between Classical and Operant Conditioning

The implications of the difference between Pavlov's and Thorndike's procedures were not fully appreciated until the work of B. F. Skinner. For example, John B. Watson, who is generally regarded as the "father" of behaviorism, did not sharply distinguish between the two procedures (Watson, 1913). Skinner realized that the classical procedure only permitted an experimental analysis of the relation between the environment and the reinforcer. Thus, the classical procedure was limited to changing the stimuli controlling responses that already could be elicited by other stimuli. Thorndike's procedure, in which a reinforcer could follow *any* response without respect to antecedent stimuli, opened the possibility of changing the full behavioral repertoire of the learner—not just elicited responses.

In *The Behavior of Organisms* (1938), B. F. Skinner's seminal extended treatment of classical and operant conditioning, he identified two procedures that he called Type S (or *respondent*) conditioning and Type R (or *operant*) conditioning. Respondent conditioning corresponded to the Pavlovian procedure. Skinner so named the procedure to emphasize that the behavior of interest (the UR) was a response (i.e., a respondent) elicited by a specified *stimulus* (the US; hence, Type S). Type R conditioning corresponds to the operant procedure, where *operant* is a term that Skinner introduced to emphasize that the response (the R; hence, Type R) operated on the environment to produce the reinforcer (see also Skinner, 1935). Skinner called the procedure Type R conditioning to emphasize that the relation of the organism's *response* to the reinforcer was paramount, and that this response was not occasioned by any specifiable stimulus. In Skinner's words, "there are two types of conditioned reflex, defined according to whether the reinforcing stimulus is correlated with a stimulus or with a response" (1938, p. 62). "The fundamental difference rests upon the term with which the reinforcing stimulus ... is correlated. In Type S it is the stimulus ..., in Type R the response" (1938, p. 109). Note especially that the two types of conditioning are "defined" (his word) by a procedural distinction, not a process distinction.

Later in the same work, Skinner cited without dissent the views of contemporaries who proposed a theoretical consistency between the conditioning process involved in the classical and operant procedures. "An analysis of differences between the two types has been made by Hilgard (1937), who points out that both types usually occur together and that 'reinforcement' is essentially the same process in both. The present distinctions [Skinner's procedural distinctions] are, however, not questioned" (p. 111). Skinner then cited the following, also without dissent: "Mowrer (1937) holds out the possibility that the two processes may eventually be reduced to a single formula" (p. 111). He noted further that "in Type R ... the process is very probably that referred to in Thorndike's Law of Effect" (p. 111). (For a presentation of Thorndike's views as they relate to current work on reinforcement, see Donahoe, 1999.) In summary, Skinner's prescient distinction between classical (respondent, or Type S) and operant (or Type R) conditioning was based on procedural grounds alone. A unified theoretical treatment of the conditioning process involved in the two procedures was a possibility that Skinner both anticipated and welcomed. The view that one fundamental conditioning process occurs in both procedures is sometimes seen as inconsistent with Skinner's treatment of conditioning. It is not (Donahoe, Burgos, & Palmer, 1993).

Factors That Produce Behavioral Change in the Classical Procedure

The classical procedure is best suited for the experimental analysis of the effects of varying the characteristics of the CS and the reinforcer (the US), and of the temporal relation between them. In contrast, the operant procedure is best suited for the experimental analysis of the effects of varying the characteristics of the response and the reinforcer, and of the temporal relation between these two events. Discriminated operant conditioning, which is considered in Catania

(Chapter 3, this volume), permits the experimental analysis of all three events—the environmental stimulus, the behavior that occurs in the presence of the stimulus, and the reinforcer.

Characteristics of the CS

A very wide variety of stimuli have been effectively used as CSs in the classical procedure. They include the usual exteroceptive stimuli—visual, auditory, and tactile stimuli—as well as interoceptive stimuli—those produced by stimulation of internal receptors. Indeed, the regulation of many intraorganismic responses, such as blood pressure, glucose levels, and other behavior mediated by the autonomic nervous system, is influenced by classical conditioning (Dworkin, 1993). Because of its pervasive effect on autonomic responses, emotional behavior is especially affected by the variables manipulated in the respondent procedure (Skinner, 1938). As one example of interoceptive conditioning, stimuli from the insertion of a needle precede the effects of an injected drug, and these stimuli become CSs for drug-related responses. The effect of such CSs can be complex. When internal receptors on neurons sense the increased concentration of the injected compound, the endogenous (internal) production of that compound by neurons is decreased. For example, cocaine raises the level of dopamine, and this increase is detected by receptors on neurons that release dopamine. (*Dopamine* is a neuromodulator that affects the activity of many other neurons because it is widely distributed in the brain. Dopamine plays an important role in drug addiction and in reinforcement.) In reaction to increases in dopamine levels, these neurons lower their rate of production of dopamine. Thus, the UR is not an increase in dopamine from the injection of cocaine, but a decrease in the production of dopamine by neurons whose receptors detect the increased levels of dopamine (which is the functional US). After repeated pairings of the injection CS with the drug, when a placebo is injected (i.e., an injection CS that is not followed by cocaine), neurons show a conditioned *decrease* in the production of dopamine. Decreases in dopamine induce withdrawal symptoms, including drug cravings. The stimulus of the injection produces a conditioned reduction in the endogenous production of dopamine (Eikelboom & Stewart, 1982; see also Sokolowska, Siegel, & Kim, 2002). Classical conditioning clearly plays an important role in dysfunctional behavior, such as drug addiction. Panic disorders are also affected by classical conditioning (e.g., Bouton, Mineka, & Barlow, 2001). The life histories of those afflicted with panic disorder often include pairings of the feared stimulus with an aversive US (Acierno, Hersen, & Van Hasselt, 1993).

Although many stimuli can function as CSs, all stimuli are not equally effective with all USs. As a laboratory example, if food is presented to a pigeon after a localized visual stimulus, the pigeon will come to peck the visual stimulus (Brown & Jenkins, 1968). This procedure, known as *autoshaping*, meets the definition of a classical procedure. Pecking, which was initially elicited by the sight of food, is now directed at a stimulus—the localized light—that reliably precedes the food. However, if food is paired with a stimulus that is not spatially localized, such as a sound, pecking is not observed, although other measures indicate that conditioning has in fact occurred (Leyland & Mackintosh, 1978). The expression of the CR depends in part on the CS with which the US is paired. Some instances of this phenomenon—called *differential associability*—arise from the past history of the individual. As an example with humans, if the textual stimulus "DON'T BLINK" is presented as a CS before a puff of air to the eye, conditioning of the eye blink is impaired relative to a neutral stimulus, such as the presentation of a geometric form. Conversely, if the CS is "BLINK," conditioning is facilitated (Grant, 1972). Interactions between the CS and US have also been shown in the conditioning of phobias. Stimuli that are often the object of phobias, such as spiders, more rapidly become CSs when paired with an aversive US, such as a moderate electric shock (Ohman, Fredrikson, Hugdahl, & Rimmo, 1976). Moreover, when the life histories of persons with phobic behavior are examined, they often contain experiences in which the object of the phobia has been paired with an aversive stimulus (Merckelbach & Muris, 1997).

Instances of differential associability also arise from the past history of the species of

which the individual is a member. For example, taste or smell stimuli more readily become CSs when paired with food and the consequences of ingestion than do visual or auditory stimuli present at the same time (Garcia, Erwin, & Koelling, 1966). If nausea is a consequence of ingestion, as with poisons, then an aversion to the food is conditioned. This phenomenon, called *taste aversion*, undoubtedly owes its occurrence to the special status that olfactory and gustatory stimuli have with respect to the ingestion of food. Over evolutionary time, such stimuli necessarily came immediately before the ingestion of food, thus meeting the relative constancy of environmental conditions required for natural selection to operate. Under constant conditions, privileged neural connections may be selected between these sensory modalities and behavior related to food intake. Taste aversions are generally affected by the same variables as other conditioned responses, although conditioning can take place over longer time intervals between the CS and the US/UR (LoLordo & Droungas, 1989). Conditioned aversions to food eaten before chemotherapy often occur because of the nausea-inducing effects of the treatment. These aversions may be reduced with appropriate conditioning regimens (Bernstein, 1991).

Characteristics of the US/UR

The stimuli that have been used as USs vary almost as widely as those used as CSs. Generally, USs may be subdivided into two classes—those that are *appetitive* (stimuli that elicit approach behavior) and those that are *aversive* (stimuli that elicit escape behavior). Appetitive USs, such as food or water, when presented to an appropriately deprived animal, evoke a range of behavior, including approaching the stimulus and consummatory responses. Similarly, aversive stimuli elicit a range of behavior, including retreating from the stimulus, attacking, and freezing when the stimulus is inescapable. The CRs conditioned to environmental stimuli can either facilitate or interfere with operants when the US occurs in an operant procedure. To interpret possible interactions of respondents with operants, it is well to remember that the total CR is not restricted to the CRs that are measured. USs generally elicit a variety of URs, some of which are less easily detected at the behavioral scale of measurement, such as heart rate changes mediated by the autonomic nervous system. For experimental analysis, the laboratory methods used to study conditioning with the classical procedure usually employ USs that reliably elicit easily detectable URs. Reflexes (US–UR relations that are products of natural selection) are especially reliable and meet these criteria.

Higher-Order Conditioning

In the larger world outside the laboratory, many stimuli that serve as effective reinforcers do not elicit responses that are readily detectable at the behavioral scale of measurement. The sight or even the thought of a stimulus that has been paired with food may function as an effective US with respect to other stimuli. (Imagine the food that you are going to eat at your next meal, particularly if it is close to mealtime. Can you detect an increase in salivation?) The sight of a favored food evokes conditioned salivation through previous pairing with that food. Subsequently, words on a menu that describes the food also evoke salivation through pairing with a picture of the food. It is no accident that the menus of fast-food restaurants contain pictures of the food being described.

Stimuli that function as reinforcers without specific prior experience with those stimuli are *unconditioned* reinforcers. Sweet-tasting substances are examples. Stimuli that function as reinforcers after pairing with another CS become *conditioned* reinforcers. In the classical procedure a stimulus becomes a conditioned reinforcer through being paired with an unconditioned reinforcer, or with an already established conditioned reinforcer. A previous CS can function as a reinforcer for a new CS because the previous CS elicits behavior (the CR) as a result of prior conditioning. This procedure is called *higher-order conditioning*, which was first studied in the laboratory by Pavlov and has since been demonstrated many times. As a laboratory example, CS1 (e.g., a tone) is first paired with food and then, after the CS1 has acquired the ability to evoke a salivary CR, a second stimulus CS2 (e.g., a light) is paired with CS1. As a result, CS2 also acquires the ability to evoke a salivary CR even though

CS2 itself has never been paired with food. If the higher-order procedure is continued and CS1 in the CS2–CS1 sequence is no longer followed by food, CS1 ceases to evoke CRs. Because CS2 is no longer followed by a stimulus that evokes behavior, CS2 also ceases to function as a CS. Responding to CS1 can be maintained by occasionally presenting CS1 alone and pairing it with food, in which case higher-order conditioning of CS2 continues for a longer period of time (Rescorla, 1980). Outside the laboratory, occasional pairings are the rule, as when money is paired with other reinforcers. If money were no longer paired with CSs and USs, it would cease to function as a reinforcer. Stimuli that become CSs by being paired with a US can also reinforce operant behavior. For example, a sound that has been paired with food can increase lever pressing in rats if lever pressing is followed by the sound (Skinner, 1938). This phenomenon is called *conditioned* (or *secondary) reinforcement* because the operant has been strengthened by a CS that has been paired with food and not the food itself. For human behavior, most reinforcers are conditioned reinforcers. Recent research at the neural level of experimental analysis has shown that conditioned reinforcers activate the same neural systems as unconditioned reinforcers, although by means of partially different neural pathways (Schultz, 2001; see also Donahoe & Palmer, 1994/2005).

Temporal Relation between the CS and the US/UR

Given an appropriate choice of CS and US, what must occur for conditioning to take place? Research over the past 100 years has identified two critical factors—the temporal relation between the CS and US/UR, and a change in ongoing behavior that is evoked by the US. The first factor, the temporal relation between the CS and the US/UR, was demonstrated by Pavlov. This factor is known as *temporal contiguity.* The second factor was not identified until the late 1960s, with the work of Leon Kamin (1968, 1969). Kamin's findings indicated that temporal contiguity alone was not enough. In addition to being contiguous with the CS, the US also had to evoke a *change* in ongoing behavior; that is, the US had to evoke a response that was not already occurring when the US was presented. Only if such a change occurred would the US function as a reinforcer. This second factor is known as a *behavioral discrepancy.*

Temporal Contiguity

The classical procedure permits an analysis of the effects on conditioning of the temporal relation between the CS and the US/UR (Gormezano & Kehoe, 1981). Experimental analysis is possible because the presentation of both stimuli can be controlled by the experimenter and the relevant behavior can be measured. Figure 2.2 shows a representative finding when the temporal relation between the onset of the CS and US is varied (Smith, Coleman, & Gormezano, 1969). Here the CS was a tone, the US was a mild shock in the vicinity of one eye of a rabbit, and the CR was movement of the nictitating membrane (NM) elicited by the shock. The NM is a semitransparent tissue that can be extended over the eyeball to protect it. This membrane is present in many animals, such as dogs and cats, but is vestigial in humans, in which only the pink tissue in the nasal corner of each eye remains. The NM response is particularly well suited for experimental analysis because movement of the membrane is very rare except when an aversive stimulus

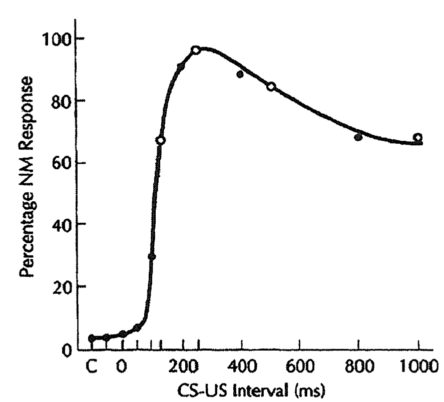

FIGURE 2.2. Effect of the CS-US interval on the strength of conditioning with the classical (Pavlovian) procedure. Different groups of rabbits were trained at each of the CS–US intervals. The CS was a tone, and the US was a mild shock in the region of the eye. The shock elicited a "blink" of the nictitating membrane (NM). From Donahoe and Palmer (1994/2005); based on findings from Smith, Coleman, & Gormezano, 1969. Copyright 2005 by John W. Donahoe. Reprinted by permission.

is applied near the eye. Thus, any movement of the NM during the CS is very likely a CR and not the result of other variables.

After a number of CS–US/UR pairings in which different animals were trained with different intervals between the CS and the US/UR, the major findings were these:

1. When the CS came *after* the US/UR (a *backward conditioning* arrangement), conditioning did not occur.
2. As the forward interval between the CS and the CS–US/UR increased, CR responding became more probable and reached a maximum when the interval attained a relatively short value (here, less than a half-second—500 milliseconds).
3. When the CS–US/UR interval increased beyond this point, CR responding declined.

To summarize, in a well-controlled Pavlovian procedure, selection by reinforcement occurs over only a relatively brief interval. As a result of reinforcement, stimuli (CSs) that reliably precede the elicitation process (US–UR) acquire control over the CR. Depending on the specifics of the training regimen, conditioning may occur in only one or a very few CS–US pairings (e.g., Kehoe & Macrae, 1994; Van Willigen, Emmett, Cote, & Ayres, 1987).

Because the conditioning process typically operates over only a very short time interval, longer-term relations between the environment and behavior must result from filling the gap between the CS and more remote US/URs with moment-to-moment changes in stimuli that serve as higher-order reinforcers. Indeed, even in tightly controlled laboratory situations with the rabbit NM, higher-order conditioning has been shown to occur over intervals as long as 18 seconds (Kehoe, Gibbs, Garcia, & Gormezano, 1979). In the more complex environments outside the laboratory and with learners whose conditioning histories are complex, the opportunities for higher-order and conditioned reinforcement are enormous. For humans especially, many such stimuli are available.

Critical Temporal Relation: CS–US or CS–UR?

In the classical procedure, the experimenter manipulates the relation between stimuli—the CS and US. By contrast, as we have seen, in the operant procedure, the experimenter manipulates the relation between a response (the operant) and a stimulus (the reinforcer, or US). Returning to the classical procedure, the experimenter directly controls the temporal relation between the CS and US, but when that relation is varied, the CS–UR relation necessarily varies as well (see Figure 2.3). Thus, it is generally impossible to determine whether the CS–US or the CS–UR relation is critical. Teasing apart these relations might appear unimportant except that the difference between the events that the experimenter manipulates in classical and operant procedures has led many to interpret the difference as more than a procedural distinction (e.g., Rescorla, 1991). Specifically, in classical procedures, the learner is sometimes said to acquire a stimulus–stimulus relation, whereas a stimulus–response relation is acquired in the operant procedure. The stimulus–response relation of the operant procedure can be appreciated by reference to Figure 2.1. Note that the reinforced operant necessarily occurs in the presence of *some* environmental stimulus. As Skinner (1937) noted, "It is the nature of [operant] behavior that ... discriminative stimuli are practically inevitable" (p. 273; see also Catania & Keller, 1981; Dinsmoor, 1995; Donahoe, Palmer, & Burgos, 1997). Thus, some environmental event is very likely to acquire control over behavior in the operant procedure even though the experimenter may not directly manipulate that relation. Because the inference that different *kinds* of relations are acquired in the two procedures rests upon the fact that the experimenter manipulates

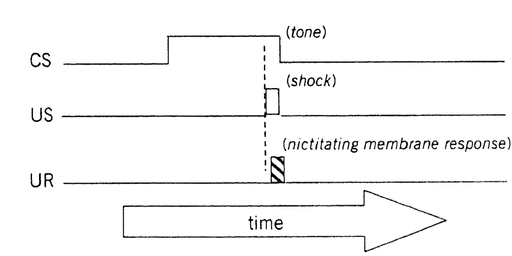

FIGURE 2.3. Schematic diagram of the events in a typical classical (Pavlovian) procedure. A specified environmental stimulus (here, a CS of a tone) precedes an eliciting stimulus (here, a US of a mild shock in the region of the eye of a rabbit) that evokes a response (here, a UR of a brief nictitating membrane response).

different events in the two procedures, it becomes important to determine whether the CS–US relation (a relation between two stimuli) or the CS–UR relation (a relation between a stimulus and a response) is fundamental in the Pavlovian procedure.

Recently, an experimental preparation has been developed in which the UR occurs with sufficient delay after the presentation of the US to separate experimentally the effects of the CS–UR relation from the CS–US relation (Donahoe & Vegas, 2004). Using the injection of water into the mouth of a pigeon as a US and swallowing as a UR, the CS could be introduced *after* the onset of the US but *before* the onset of the UR. Thus, the CS–US relation was backward, a relation that does not generally promote conditioning. Also, the swallowing UR lasts longer than the NM response, which allows the CS to be introduced *after* the onsets of both the US and UR but still overlap the UR. The central finding was that the CS (a light) came to evoke the conditioned response (swallowing) independently of the relation of the CS to the US as long as the CS preceded and/or overlapped the UR. Thus, conditioning in the classical procedure varied more systematically with the temporal relation between the CS and UR than with the relation between the CS and US. The inference that the learner acquired a different *kind* of relation with the classical procedure—a relation between two environmental events (CS–US) instead of an environment–behavior relation (CS–UR)—was based on a misinterpretation of the finding that variations in the CS–US relation affected conditioning. Conditioning in both the classical and the operant procedures changes the environmental control of behavior.

Behavioral Discrepancy Produced by the Reinforcing Stimulus

Until experiments conducted by Leon Kamin in the late 1960s, temporal contiguity between the CS and the US/UR was thought to be enough to produce conditioning in the classical procedure. Kamin's experiments showed that something more was needed, and many subsequent experiments have confirmed and extended his findings by using a variety of methods with both classical and operant procedures (e.g., Rescorla & Wagner, 1972; Vom Saal & Jenkins, 1970). Previous studies had pointed in a similar direction, but their significance was not fully appreciated (e.g., Johnson & Cumming, 1968; Rescorla, 1967). What was that "something more"?

Kamin devised a multiphase classical procedure known as the *blocking design*, which is summarized in Table 2.1. In the experimental group of animals, CRs were conditioned to CS1 during Phase 1. Then, in Phase 2, CS1 continued to be paired with the US, but CS1 was now accompanied by CS2, a stimulus that came on and went off at the same time as CS1. It is important to note that the temporal relation of CS2 to the US/UR should have been enough to condition responding to CS2 if contiguity were all that was required: The temporal relation of CS2 with the US was the same as with CS1, which did acquire CRs. In the Test Phase, CS1 and CS2 were presented separately to determine whether each stimulus had acquired the CR. As shown in Table 2.1, conditioned responding occurred to CS1 but not to CS2. An otherwise effective temporal relation of CS2 to the US did not condition a CR. In technical terms, prior conditioning to CS1 had *blocked* conditioning to CS2.

TABLE 2.1. The Experimental Design Used to Demonstrate the Role of Behavioral Discrepancy in Conditioning

	Experimental group	Control group
Conditioning phase 1	CS1 (tone) ⟶ US (food)	CS3 (click) ⟶ US (food)
Conditioning phase 2	CS1 (tone) plus CS2 (light) ⟶ US (food)	CS1 (tone) plus CS2 (light) ⟶ US (food)
Test phase	CS1 (tone) presented alone—CR CS2 (light) presented alone—no CR	CS1 (tone) presented alone—CR CS2 (light) presented alone—CR

Note. In the experimental group, conditioning to CS2 was *blocked* by prior conditioning to CS1.

One possible interpretation of the lack of conditioning to CS2 is that two CSs cannot be simultaneously conditioned to the same US. Various control experiments eliminated this possibility. In one control experiment, animals were first conditioned to an unrelated stimulus, CS3, during Phase 1 (see Table 2.1). Next, during Phase 2, animals in the control group received the same training as the experimental group—CS1 and CS2 were simultaneously presented and paired with the US/UR. Now, when CS1 and CS2 were presented separately during the Test Phase, each stimulus evoked a CR. Thus, two stimuli could be simultaneously conditioned to the same US, and the explanation of blocking must be sought elsewhere.

A compelling explanation of blocking was first offered by Robert Rescorla and Allan Wagner (1972). Stated in behavioral terms instead of the associationist language of the original formulation, a stimulus becomes a CS when—in addition to an appropriate temporal relation to the UR—the UR that is evoked by the US differs from the behavior that was occurring just before the US was presented (Donahoe, Crowley, Millard, & Stickney, 1982; Stickney & Donahoe, 1983). Technically speaking, the US must evoke a *behavioral discrepancy*, which was the "something more." Blocking of conditioning to CS2 occurred during Phase 2 for the experimental group because CS1 was already evoking the CR (e.g., salivation) *before* the US evoked the UR (also salivation). The UR did not constitute a sufficient change in ongoing behavior to support new conditioning. In the control group, however, when the CS was presented during Phase 2, it accompanied a stimulus, CS1, that did *not* evoke a CR and, consequently, both CS1 and CS2 became effective conditioned stimuli.

The significance of the behavioral-discrepancy requirement is that a stimulus must evoke a *change* in behavior if it to function as a reinforcer. In the vernacular, the learner must be "surprised" to receive the stimulus (more precisely, to respond in the way evoked by the stimulus). Natural selection has selected neural mechanisms of conditioning that come into play only when the environment causes the organism to change its ongoing behavior. As a possible practical example, parents who lavish praise independently of the behavior of the child may find that their praise is ineffective as a reinforcer. Frequent and indiscriminate praise is not "surprising." Conversely, parents who dole out praise sparingly may find the same words to be quite effective reinforcers. The more deprived the learner is of contact with a stimulus, the more vigorous the behavior evoked by that stimulus, and the more effectively it can function as a reinforcer (cf. Donahoe, 1997; Premack, 1959; Timberlake & Allison, 1974).

A Unified Principle of Reinforcement

Our present understanding of selection by reinforcement may be summarized as follows: If a stimulus evokes a change in ongoing behavior (a behavioral discrepancy), then that stimulus can function as a reinforcer with respect to the environmental and behavioral events that immediately precede and accompany the discrepancy (temporal contiguity) (Donahoe, Burgos, & Palmer, 1993; Donahoe et al., 1982).

As shown in Figure 2.1, in the classical procedure, the stimulus that reliably precedes the discrepancy is the CS, and the behavior that reliably accompanies the discrepancy is the UR. As also shown in Figure 2.1, in a simple operant procedure, no particular stimulus reliably precedes the discrepancy, and the responses that accompany the discrepancy are the operant and the UR. Thus, both the operant and the CR are acquired in the operant procedure. The basic conditioning process (selection by reinforcement) appears to be the same in both the classical and operant procedures. However, the events that reliably accompany the discrepancy in the two procedures are different and, consequently, the outcomes of the two procedures are different. In the classical procedure a specific stimulus (the CS) gains control over a specific response (the CR), but whatever other responses occur at the time of the discrepancy are unspecified. In the operant procedure, two specific responses (the operant and the CR) are acquired, but whatever antecedent stimuli that permit the operant to be emitted are not specified. (As already noted, a discriminated operant procedure can specify the antecedent stimuli.) Because the reinforcement process appears to be fundamentally the same in the classical and operant procedures, it is known as the *unified* reinforcement principle (Donahoe et al., 1982).

In the classical procedure, no behavior other than the UR reliably accompanies a discrepancy, and in the simple operant procedure, no environmental stimulus reliably precedes the discrepancy. However, this does not necessarily mean that no response other than the CR is acquired in the classical procedure, or that no stimulus controls behavior in the operant procedure (Donahoe et al., 1997). To the extent that conditioning is possible with only a single occurrence of a discrepancy, other responses may inadvertently be conditioned in the classical procedure, and stimuli may acquire control of the operant in the operant procedure. Skinner (1948) demonstrated that when reinforcers are presented independently of an animal's behavior, a response may nevertheless be conditioned. The responses that are acquired are those that happen by chance to precede the reinforcer, and these responses are often those evoked by the reinforcer. Thus, a pigeon that is given occasional presentations of food independent of its behavior may begin to pace beside the wall adjacent to the feeder (Staddon & Simmelhag, 1970; Timberlake & Lucas, 1985). Pacing can then be strengthened by subsequent presentations of food. Skinner referred to this phenomenon as *superstitious conditioning*. An analogous phenomenon has been discovered in the classical procedure (Benedict & Ayres, 1972). When a CS and a US are presented independently of one another, chance CS–US pairings sometimes cause the CS to acquire control of the CR, especially when the chance pairings occur early in training.

On a single occasion, the conditioning process cannot distinguish between a chance and a nonchance pairing of an event with a reinforcer. In Pavlov's procedure, perhaps the dog pricked up its ears when hearing the metronome before food was given. The behavior of pricking the ears might be strengthened in the presence of the sound of the metronome, not merely the CR of salivating. Similarly, in Thorndike's procedure, the animal may have looked at the mechanism that released it from the puzzle box to obtain food. Visual stimuli produced by the mechanism may come to control the response of escaping the puzzle box as well as salivation. It is only with repeated experience that chance and nonchance pairings can be distinguished and—more generally—that the classical procedure can be distinguished from the operant procedure. A unified reinforcement principle accommodates the behavioral changes produced by both procedures while also accommodating—even predicting—the occasional emergence of superstitious conditioning in both procedures. Natural selection has produced a conditioning process that is most sensitive to *reliable* relations between the environment and behavior, but the process is not infallible.

Finally, some further comment on the nature of the discrepancy is useful. As noted in the discussion of higher-order and conditioned reinforcement, a stimulus may function as a reinforcer if it engages the neural processes that underlie reinforcement. This is true whether or not those neural processes are accompanied by responses that are detectable at the behavioral scale of measurement. What the experimental analysis of behavior has shown is that the behavior evoked by the reinforcer is more closely linked in time to those neural processes than to the presentation of the reinforcing stimulus; that is, the CS–*UR* temporal relation is more critical than the CS–*US* relation. Considerations of natural selection are consistent with this finding. The *behavior* of the organism is the focus of selection, not the reception of stimuli except as their reception affects behavior. Thomas Huxley, Darwin's stalwart defender, put it this way: "The great end of life is not knowledge, but action." If the behavioral expression of conditioning were not highly correlated with the neural processes that mediate reinforcement, then those processes could not have been naturally selected in the first place. Nevertheless, once those processes have been naturally selected, their behavioral expression is not necessary for the environment to engage them. The neural events that accompany a behavioral discrepancy are the same as those engaged by higher-order and conditioned reinforcing stimuli even though the discrepancy may not be readily detectable at the behavioral level (Schultz, 1997, 2001; see also Donahoe & Palmer, 2005). These neural events must be investigated through the experimental analysis of neuroscience, not behavior. As Skinner recognized: "The ... gap between behavior and the variables

of which it is a function can be filled only by neuroscience, and the sooner ... the better" (Skinner, 1988, p. 460).

Some Phenomena Associated with the Classical (Respondent) Conditioning Procedure

Thus far, we have been concerned with *acquisition* of environment–behavior relations using the classical procedure and with the process of *reinforcement* that produces acquisition. In this final section, we examine a number of phenomena that accompany the acquisition of CS–CR relations.

Maintenance of Conditioning

The acquisition of conditioning proceeds most rapidly when every presentation of the CS is followed by a reinforcer—whether an unconditioned or conditioned reinforcer. However, once CRs have been acquired, behavior can be maintained at high levels with less frequent reinforcement. The left panel of Figure 2.4 shows the acquisition of CRs in the rabbit NM preparation. During acquisition, every presentation of the CS was followed by the US/UR. The three groups of animals then received different percentages of CS–US/UR pairings. One group continued to receive reinforcers following 100% of CS presentations, and responding was maintained at the same high level as during acquisition. The remaining two groups received a *gradually* reduced percentage of reinforcement. In one group the CS was ultimately followed by the US/UR on 50% of the trials and, in the other group on only 25% of the trials. As shown in the middle panel of Figure 2.4, performance was relatively unchanged even though the percentage of reinforced CSs was reduced to quite low values. When every CS presentation is followed by the US/UR, the procedure is called *continuous* reinforcement; when only some CSs are followed by the reinforcer, it is called *intermittent* reinforcement. In those terms, efficient acquisition of CRs requires continuous reinforcement, but responding can be maintained by the gradual introduction of intermittent reinforcement.

Stimulus Generalization

During acquisition, the stimulus that reliably precedes the reinforcer is the CS. However, the CS is not the only stimulus whose control of the CR is affected by the conditioning process. First, other stimuli that share prop-

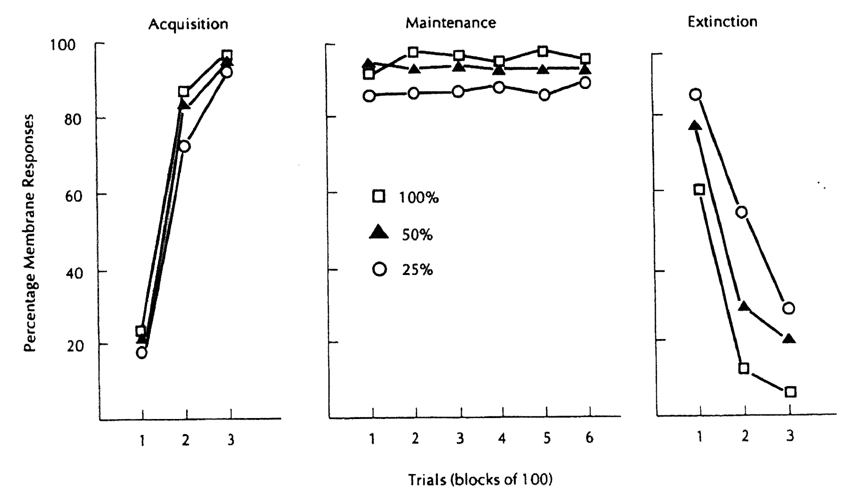

FIGURE 2.4. Acquisition, maintenance, and extinction of a classically conditioned nictitating membrane response in the rabbit. During acquisition, 100% of the CSs were followed by the US. During maintenance, different groups of animals received either 100, 50, or 25% CS–US pairings. During extinction, CS presentations were not followed by the US. From Donahoe and Palmer (1994/2005; based on findings from Gibbs, Latham, & Gormezano, 1978). Copyright 2005 by John W. Donahoe. Reprinted by permission.

erties in common with the CS also come to evoke the CR, although with less strength. For example, if the CS is a tone with a frequency of 1,000 Hertz (Hz), then tones of 800 Hz will likely evoke CRs, although to a lesser degree. Similarly, tones of 600 Hz may also evoke CRs, but to an even lesser degree. Other stimuli acquire the ability to evoke CRs in proportion to their physical similarity to the training CS. This phenomenon, known as *stimulus generalization*, has been documented in many classical procedures with both humans and nonhumans (e.g., Gynther, 1957; Hupka, Liu, & Moore, 1969). The experimental analysis of neuroscience is consistent with the behavioral analysis. Responding to a generalization stimulus occurs to the extent that the generalization stimulus activates the same sensory neurons as the training stimulus (Thompson, 1965). A second source of stimulus generalization arises from whatever other stimuli accompany the CS. These stimuli provide the *stimulus context*. The stimulus context seldom evokes the CR by itself because control by contextual stimuli is blocked by the more reliably present CS. However, the CS together with contextual stimuli furnish the full stimulus compound with which the US/UR is paired, and the context does affect responding (Burns, Burgos, & Donahoe, 2011; Donahoe et al., 1997). Contextual stimuli are sometimes said to function as *occasion-setters* (Grahame, Hallam, & Geier, 1990).

Control by CR-Related Interoceptive Stimuli

As conditioning proceeds, the CR begins to occur during the CS prior to the presentation of the US/UR. Thus, CR-produced stimuli begin to appear before acquisition is complete. As a result, these interoceptive events bear a temporal relation to the behavioral discrepancy that permits them also to control the CR. In an illustrative study, an appetitive US (food) was paired with an aversive stimulus (a moderate electric shock) *after* the CS had been paired with food. (Pairing eliciting stimuli that evoke competing URs is a *counterconditioning* procedure; cf. Richardson & Donahoe, 1967) After food had been paired with shock, when the CS was presented food-related CRs were weakened (Colwill & Rescorla, 1985; Holland & Rescorla, 1975; see also Donahoe & Burgos, 2000). Note that food-related CRs were weakened even though the CS itself had never been paired with shock. This phenomenon is known as *revaluation* in the sense that the "value" of the food US had been lessened by pairing food with shock. The interpretation of this finding is that pairing food with shock changed the interoceptive stimuli that, together with the CS, jointly control the CR, and this change weakened food-related CRs. Clearly, the CR is affected by a complex array of stimuli that includes the effects of stimulus generalization and control by contextual and interoceptive stimuli.

Extinction

After a CS has acquired control of a CR, control may be weakened by presenting the CS but omitting the US. This is an *extinction* procedure. The effect of an extinction procedure on conditioned responding is shown in the right panel of Figure 2.3. The percentage of CS presentations that evoked a CR decreased progressively over the course of extinction. Figure 2.3 also demonstrates another effect: the rate of decrease in responding was slower after intermittent reinforcement than after continuous reinforcement. The responding of animals that received 100% reinforcement throughout training decreased most rapidly, followed successively by animals receiving 50% and 25% reinforcement.

Punishment

Punishment is a term that applies only to the operant procedure. In punishment, the operant response produces a stimulus that *decreases* the strength of the operant. As a laboratory example, lever pressing that is reinforced with food can be punished by the occasional presentation of a moderate electric shock. Food-reinforced lever pressing declines under this procedure, and shock is said to function as a *punisher*. By contrast, conditioning with the classical procedure always produces an increase in responding, that is, an increase in the behavior elicited by the US. Although punishment occurs only in operant procedures, conditioning in the classical procedure is relevant because CRs contribute to punishment. Specifically, CRs and operants are acquired together, and CRs can decrease the operant strength if the operant and the CR are incompatible (Donahoe & Palmer, 1994/2005). In the preceding example, food conditions lever pressing, whereas shock conditions escape from the lever, as well as autonomic responses (Borgealt, Donahoe, & Weinstein, 1972). Because the organism cannot press the lever while simultaneously escaping from the region with the lever, lever pressing declines. The recovery of lever pressing from punishment depends on the prior extinction of escape responses (Estes & Skinner, 1941).

Certain paradoxical effects of punishment procedures can be understood as the product of interactions between operants and respondents. Monkeys restrained in a chair were first trained to bite a rubber hose for food. This is an operant task, with biting as the operant and food as the reinforcer. The procedure was then changed such that biting the hose, in addition to producing food, occasionally produced an electric shock to the tail. Electric shock applied to the tail of a monkey is a stimulus that elicits biting the hose. Biting is a component of aggressive behavior that is often elicited by aversive stimuli. Instead of reducing the rate of biting the lever, the addition of shock increased the rate of biting, particularly at the times when shock was most likely to be presented. In fact, in many cases, food could be eliminated altogether, and the monkey would continue to bite the hose, the only consequence of which was now the occasional delivery of shock (Branch & Dworkin, 1981; Morse & Kelleher, 1977). This "masochistic" behavior is understandable, at least in part, as a case in which the operant that produced food and the respondent evoked by shock were similar—biting.

Some Implications of Classical Conditioning for Applied Behavior Analysis

Most human behavior of interest comes under environmental control as a result of operant, not respondent, procedures—that is, response–reinforcer, not stimulus–reinforcer, contingencies. Similarly, many techniques used to modify dysfunctional behavior employ operant rather than respondent procedures. Nevertheless, an understanding of the conditioning process as revealed by the classical procedure is important for two principal reasons. First, operant contingencies necessarily include stimulus–reinforcer contingencies: Some environmental stimulus always precedes the reinforcing stimulus (or US; see Figure 2.1). Thus, reinforcer-related responses (CRs) are inevitably acquired in operant procedures. Second, current accounts of operant and classical procedures indicate that both procedures engage the same fundamental conditioning process: whatever stimuli precede the behavioral discrepancy acquire control over whatever responses precede and accompany the discrepancy. In the classical procedure, these stimuli are the CS (and whatever other stimuli accompany the CS) and the behavior is the CR (components of the UR). In the operant procedure, the stimuli are those that precede the discrepancy (discriminative stimuli in discriminated operant procedures), and the behavior is the operant in addition to the UR. The remainder of the chapter indicates some general implications for applied behavior analysis (ABA) that arise from research using the classical procedure.

What Stimuli Control Behavior in the Natural Environment?

The stimuli that control behavior are those that reliably occur in the natural environment prior to the reinforcer. The stimuli controlling behavior in the natural environment are those that reliably occurred before reinforcers in the past. The history of reinforcement cannot be fully known, of course, but the controlling stimuli may be identified by noting the situations in which the behavior now occurs. If the behavioral changes produced by a therapeutic environment are to persist, three guidelines are useful:

1. *To the extent possible, the remedial environment should include stimuli that control the target behavior in the natural environment.* In this way, stimulus generalization from the remedial to the natural environment is maximized (Stokes & Baer, 1977). To determine the controlling stimuli, the conditions in the natural environment that precede the dysfunctional behavior should be identified.
2. If the behavior conditioned in the remedial environment is controlled by stimuli that do not occur in the natural environment, then *stimuli from the remedial environment must be introduced into the natural environ-*

ment. This applies whether the intervention seeks to establish appropriate behavior or behavior that competes with dysfunctional behavior. The result of conditioning is always a change in the environmental guidance of behavior. Reinforcers do not select responses; they select environment–behavior relations (Donahoe et al., 1997).

3. *The contingencies of reinforcement that maintained the dysfunctional behavior in the natural environment should be supplemented or replaced by alternative contingencies that maintain the behavior reinforced in the remedial environment.* To identify the reinforcement contingencies that maintain dysfunctional behavior, the conditions in the natural environment that follow the dysfunctional behavior should be determined. Reinforcers of dysfunctional environment–behavior relations must either be removed or competing behavior must be established that minimizes contact with these reinforcers. No behavioral intervention can "inoculate" the person against the effect of continuing encounters with adverse reinforcement contingencies in the natural environment.

Stimuli from the remedial environment that have acquired control over alternative behavior can be introduced into the natural environment in several general ways. First, these stimuli may be explicitly added to the natural environment. As a simplistic example, to control profligate spending a red card might be paired with an aversive stimulus (US) in the remedial environment. The card could then placed in the person's wallet so that, in the natural environment, the card would be seen before the money is accessible. Second, verbal responses may be conditioned to stimuli present in the natural environment, and these responses may in turn generate verbal stimuli that control alternative behavior. Continuing with the example of profligate spending, every time the person opens his wallet, he might be reinforced in the remedial environment for asking, "Do I really need to buy this?"

Verbal stimuli are potentially among the most effective stimuli to control behavior in the natural environment because the verbal responses that produce them are not dependent on external support in the same way as nonverbal responses. Verbal responses, and the stimuli they produce, are potentially within the behavioral repertoire of the organism in any environment—unlike seeing the red card, which is dependent on its prior placement in the wallet. A second advantage of verbal stimuli is that they can be produced by subvocal verbal behavior, and subvocal behavior cannot be subjected to contingencies of reinforcement by others. Others can ask why the red card is in the wallet because they too can see the red card. But others cannot ask why a particular "thought" occurred (a subvocal verbal response). Subvocal behavior is private behavior—that is, behavior whose stimulus properties are detectable only by the person emitting it (Donahoe & Palmer, 1994/2005; Skinner, 1957). If verbal responses—whether vocal or subvocal—are to be maintained, however, they too must be followed by reinforcers. Private behavior, sometimes called "cognitive behavior," is not immune to the conditioning processes that affect all behavior.

What Responses Are Maintained by the Natural Environment?

As we have seen, behavior is maintained in an environment to the extent that the environment contains stimuli in whose presence the behavior is reinforced. In the absence of reinforcement, an extinction procedure is implemented and responding decreases even when the training and testing environments are identical. Intermittent reinforcement during conditioning increases resistance to the effects of extinction, but responding will not continue indefinitely. Thus, the natural environment must contain reinforcers for the behavior established in the remedial environment. If dysfunctional environment–behavior relations continue to be reinforced in the natural environment, then—even if the long-term effects of the behavior are maladaptive—the dysfunctional behavior will recur and be maintained by these more immediate reinforcers. Behavior that has undergone extinction in the remedial environment will reappear in the natural environment if the remedial environment does not contain all of the stimuli that control dysfunctional behavior in the natural environment. These stimuli foster the resurgence of the maladaptive behavior where it may again be reinforced (Epstein & Skinner, 1980). The recurrence of behavior after extinction is called *spontaneous recovery* (Estes, 1955; Skinner, 1938). The remedial environment cannot "inoculate" behavior against the effects of reinforcers for dysfunctional behavior.

Addiction provides a particularly striking example of the recurrence of dysfunctional behavior. Research with the classical procedure has shown that CRs evoked early in the conditioning process give rise to stimuli that come to control the CR jointly with the CS. The phenomenon of revaluation documents the existence of control by CR-related stimuli. In the treatment of addiction, "physical dependence" may be eliminated by withholding the substance in the remedial environment. However, to the extent that the remedial environment differs from the natural environment in which the addiction was acquired, drug-related CRs will recur when the person is returned to the natural environment. Moreover, drug-related operant behavior will also recur to the extent that it is controlled by interoceptive stimuli from drug-related CRs. To reduce resurgence of drug-related CRs and the untoward effects of the stimuli they produce, the remedial environment must gradually introduce stimuli that are CSs for these CRs—possibly including even drug paraphernalia—and withholding reinforcement in their presence.

Environment–behavior relations that are selected in the remedial environment will endure if the reinforcers that previously maintained dysfunctional behavior are no longer encountered and newly established immediate reinforcers are available for effective behavior. Eliminating previously encountered reinforcers requires changing the natural environment—often a daunting task—or establishing behavior in the remedial environment that reduces contact with those reinforcers. For someone with an alcohol addiction, a simplistic example of the latter would be taking a route that does not pass by the local pub and being greeted by an adoring partner upon arrival at home. Important sources of immediate reinforcement for behavior that has been established in a remedial environment are the stimuli that are produced by such behavior. For example, behavior such as fluently reading or facilely writing a passage produces stimuli that are discriminated as characteristic of "a job well done." The stimuli produced by such behavior have previously occurred in the remedial environment and have been the occasion for praise (a reinforcer) from a teacher. Because they have been paired with praise, these stimuli have become CSs and can function as conditioned reinforcers (Catania, 1975). However, to maintain their status as conditioned reinforcers, these stimuli must continue to be paired with reinforcers. Being literate may enhance one's ability to get a job, but the environment must provide jobs if the stimuli produced by literate behavior are to endure as conditioned reinforcers. Environment–behavior relations track the momentary contingencies of reinforcement, not remote consequences. In the long run, remedial interventions are no more effective than the contingencies encountered in the natural environment. To be otherwise would contradict all that is known from the experimental analysis of respondent and operant procedures—an effort begun by Pavlov and Thorndike over 100 years ago.

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