10

Extinction of Conditioned Behavior

Did you know that

- extinction not only decreases responding, it also increases the variability of behavior and produces frustration?
- extinction involves learning to inhibit a previously conditioned response but does not fully eliminate what was previously learned?
- extinguished behavior is highly context specific and responding can reappear under a wide range of circumstances, creating challenges for behavior therapies based on extinction?
- extinction learning involves several different processes, including decreases in attention, partial weakening of prior associations, new inhibitory stimulus–response (S–R) associations, new associations with frustration signals, and hierarchical negative occasion-setting associations?
- much contemporary research is devoted to finding ways to increase the effectiveness of extinction procedures, as well as to gain a better understanding of the psychological and neurobiological mechanisms involved in extinction?
- using a larger reinforcer during training, conducting additional training trials, or providing continuous as opposed to intermittent reinforcement does not necessarily increase the persistence of behavior in extinction?

https://doi.org/10.1037/0000363-010
The Essentials of Conditioning and Learning, Fifth Edition, by M. Domjan and A. R. Delamater

Our discussion of classical and instrumental conditioning to this point has centered on various aspects of the acquisition and maintenance of conditioned behavior. Learning is important because it provides needed flexibility in how individuals interact with their environment. But if learned behavior is an adaptation to a changing environment, then the loss of conditioned behavior should be just as useful. Reinforcement schedules do not always remain in effect throughout an individual's lifetime. Responses that are successful at one point in life may cease to be useful as circumstances change. Children, for example, are praised for drawing crude representations of people and objects in nursery school, but the same type of drawing is not considered appropriate if drawn by a high school student.

Acquisition of conditioned behavior involves procedures in which a reinforcing outcome or unconditioned stimulus (CS) is presented. **Extinction** involves omitting the reinforcer or unconditioned stimulus (US). In classical conditioning, extinction involves repeated presentations of the CS without the US. In instrumental conditioning, extinction involves no longer presenting the reinforcer when the individual makes the instrumental response. The typical result of an extinction procedure is that conditioned responding declines. Thus, extinction appears to be the opposite of acquisition. Indeed, that is how extinction has been characterized in traditional theories of learning, such as the Rescorla–Wagner model (see Chapter 6). However, as the evidence described in the present chapter shows, this view of extinction is grossly incomplete.

It is important to distinguish extinction from forgetting. Although both involve the loss of conditioned responding, **forgetting** results from the passage of time. Extinction, by contrast, occurs as a consequence of repeated presentations of the CS alone or repetitions of the instrumental response without the reinforcer. Unlike forgetting, extinction is produced by a particular procedure, not merely the passage of time.

Although research on extinction originated about a hundred years ago, extinction remains a major area of contemporary research at the level of both behavior and neural mechanisms (Bouton et al., 2021; Delamater & Westbrook, 2014). Contemporary research is motivated by efforts to better understand various novel extinction phenomena and by efforts to develop more effective therapeutic procedures for the treatment of maladaptive fears and phobias (Dunsmoor et al., 2015; Maren & Holmes, 2016; Marković et al., 2021).

EFFECTS OF EXTINCTION PROCEDURES

Imagine looking forward to getting home after a hard day's work and discovering that your key no longer opens the front door. This illustrates the basic procedure for extinction. A previously reinforced response (turning the key in the lock) is no longer effective in producing the reinforcer (opening the door). Such an unexpected absence of reinforcement produces both emotional and behavioral effects. The emotion you feel upon finding that your key no longer works is **frustration** and perhaps anger. Chances are you will not give up after your first attempt to open the door but will try several more times, perhaps jiggling the key in different ways. If none of these response variations works, you will eventually quit trying.

This example illustrates two basic behavioral effects of extinction. The most obvious is that responding decreases when the response no longer results in reinforcement. This is the primary behavioral effect of extinction, and the effect that has occupied most of the attention of scientists. The other important behavioral consequence of extinction is an increase in response variability (Neuringer et al., 2001). When your key failed to open the door on the first try, you jiggled the key in various ways in an effort to make it work. That reflects the increase in response variability that is produced by extinction.

In addition to these behavioral effects, extinction often also involves emotional components. Frustration and anger occur if an expected appetitive reinforcer is withheld, and relief occurs when an expected aversive event fails to occur. We discuss relief in greater detail in Chapter 12, where we consider the extinction of avoidance behavior. In this chapter, we focus on the extinction of responses that have been conditioned with an appetitive US or positive reinforcer.

The emotional reaction of frustration has played a prominent role in analyses of extinction following various forms of appetitive conditioning. Whether nonreinforcement results in frustration depends critically on the individual's prior history. If your partner never made you coffee in the morning, you will not be disappointed if the coffee is not ready when you get up. If you never received an allowance, you will not be disappointed when you don't get one. It is only the omission of an expected reward that creates disappointment or frustration (Amsel, 1958). This prerequisite for experiencing frustration is similar to the prerequisite for inhibitory conditioning that we discussed in Chapter 5. We learned there that the absence of a US is significant only in the face of the expectancy of that US.

WHY DOES CONDITIONED RESPONDING DECLINE IN EXTINCTION?

The procedures for extinction are remarkably simple: Stop presenting the US or the reinforcer. Unfortunately, this simplicity belies the complexity of extinction effects. The decline in conditioned behavior that occurs with extinction is determined by various mechanisms, not all of which are well understood. Perhaps the simplest explanation of the response decline is that it reflects the unlearning of the original conditioned response. This is the interpretation adopted by the Rescorla–Wagner model, which we discussed in Chapter 6. Although unlearning may occur during the course of extinction (Delamater et al., 2021), as we will see, unlearning is clearly not the whole story.

Pavlov was perhaps the first investigator to recognize that extinction could not be entirely explained in terms of unlearning and proposed that extinction involves some form of response inhibition. According to this view, extinction results in new learning that serves to suppress the previously conditioned response. Specifying in greater detail what this new learning might be has occupied investigators ever since.

Some have suggested that extinction involves the learning of an association between a CS and the absence of the US, or an association between instrumental response and the omission of the reinforcer (e.g., Konorski, 1967; Pearce & Hall, 1980). Others have emphasized the emotional or frustrative effects of the sudden absence of the US or reinforcer when extinction is introduced (Amsel, 1958; Papini, 2003). Frustration is an aversive emotion. In a sense, the frustration that follows a response in extinction serves to punish that response. The pairing of an instrumental response with the aversive state of frustration could result in the learning of a new R–O (response–outcome) association, where "O" in this case is a state of frustration. Alternatively, extinction training could result in learning a new **inhibitory S–R association** (Rescorla, 2001), where the animal learns to actively not make the response. The concept of an inhibitory stimulus–response, or S–R, association is analogous, but opposite, to the excitatory S–R association in Thorndike's law of effect that we discussed in Chapter 7.

Only one of the various possible mechanisms of extinction that have been investigated assumes that extinction is the reverse of acquisition and involves unlearning. All the other mechanisms posit that extinction results in the learning of something new that suppresses conditioned responding. This leaves the possibility that what was originally learned might be restored under the right circumstances. In the next section, we consider what some of those circumstances might be.

EVIDENCE OF RECOVERY FROM EXTINCTION

The study of extinction phenomena dates back to the work of Pavlov, more than a century ago. Interestingly, evidence of recovery from extinction has an equally long history. Contemporary investigators are particularly interested in mechanisms of recovery from extinction for what these effects say about the underlying processes of extinction. Studies of the circumstances under which extinguished behavior shows recovery are also of clinical interest because extinction is an important part of behavior therapy. In this section, we consider three prominent recovery effects: spontaneous recovery, renewal, and reinstatement.

Spontaneous Recovery

The basic procedure for extinction following Pavlovian conditioning involves repeatedly presenting the CS by itself. This makes the procedure for extinction similar to the standard procedure for habituation. Indeed, Pavlov's own view was that extinction resulted in new inhibitory learning that was directed to the CS itself, an idea that is highly reminiscent of the reduced attention being paid to the stimulus that we encountered when discussing habituation (e.g., S. J. Robbins, 1990). Therefore, it is not surprising that many behavioral features of habituation are also found in extinction. One prominent feature of habituation is that it shows spontaneous recovery. If a substantial period of rest is introduced after a series of habituation trials, the habituated response is observed to return or recover.

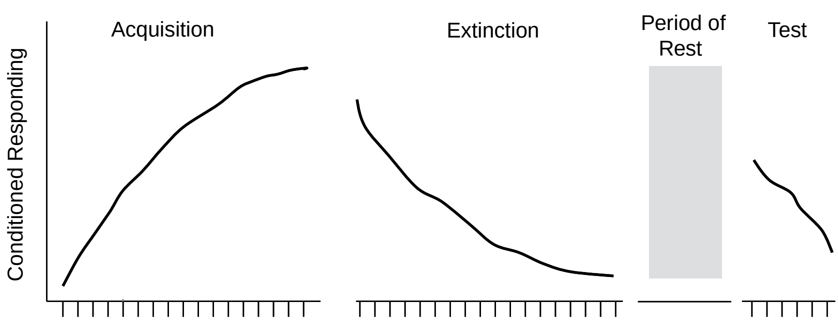
Pavlov discovered a similar phenomenon in extinction after the conditioning of a salivary response. The basic finding is illustrated in Figure 10.1. During acquisition, conditioned responding increases as a function of trials. In extinction, responding declines. A period of rest is then introduced, followed by additional extinction trials. Notice that responding is higher after the period of rest than it was at the end of the first series of extinction trials. This recovery of behavior called **spontaneous recovery** because it does not require a special intervention other than the passage of time (Rescorla, 2004).

Spontaneous recovery typically does not restore responding to the high level that was achieved in acquisition. However, the fact that responding recovers to any extent is evidence that extinction suppressed rather than completely eliminated conditioned responding. Spontaneous recovery is one reason that bad habits or maladaptive fears can return after efforts to extinguish them.

The Renewal Effect

Another strong piece of evidence that extinction does not result in complete unlearning is the phenomenon of renewal identified by Mark Bouton and his colleagues (Bouton, 2017). **Renewal** refers to a recovery of acquisition performance when the contextual cues that were present during extinction are changed. The change may be a return to the context of original acquisition or a shift to a "neutral" context. Renewal is particularly troublesome for behavior therapy because it means that problematic fears that are extinguished in the context of a therapist's office can return when the client returns to work or

FIGURE 10.1. Illustration of Spontaneous Recovery Following Extinction



Note. During the acquisition phase, conditioned responding increases. In the subsequent extinction phase, responding declines to the low level seen at the start of the acquisition phase. A period of rest is then introduced, during which training trials are suspended. This results in a temporary recovery of the conditioned behavior. (Data are hypothetical.)

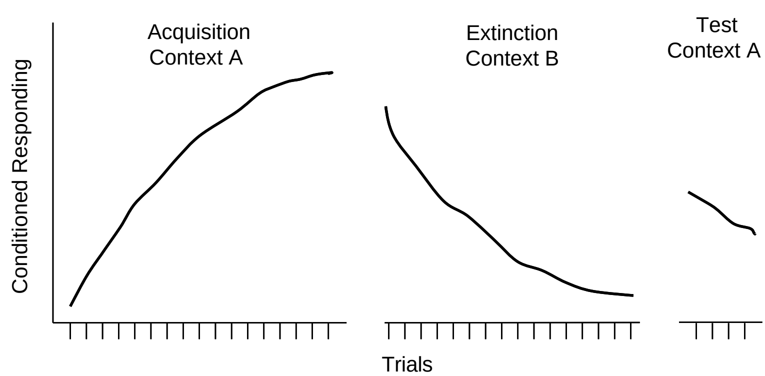
home. Similarly, a bad drug habit that is extinguished in a residential treatment center can be renewed when the client is discharged and has to live somewhere else.

The renewal effect was discovered during the course of research on transfer of training (Bouton, 1993). The basic question in these studies was how learning that occurs in one situation transfers to other circumstances or contexts. For example, if you learn something in a noisy dormitory lounge, will that learning transfer to a quiet classroom in which you have to take a test? An equally important question concerns the transfer of extinction. If extinction is conducted in one situation so that the CS no longer elicits responding in that context, will the CS also be ineffective in eliciting the CR in other situations?

Research on the renewal effect was originally conducted with laboratory rats, but the phenomenon has since been extended to human participants (Vervliet et al., 2013). A schematic representation of the results of a renewal experiment is presented in Figure 10.2. In the first phase of the experiment, participants received acquisition training in a particular place, labeled Context A. Context A may be an experimental chamber or room distinguished by a particular level of illumination, odor, and flooring. As you might expect, conditioned responding increased during the acquisition phase. The participants are then moved to another experimental chamber (Context B), in which the lighting, odor, and flooring are different. Extinction is conducted in this alternate context. As is common, responding declines with repeated extinction trials. At the end of the experiment, the participants are returned to Context A to see if the effects of extinction conducted in Context B transfer back to Context A.

If extinction involves the complete unlearning of a conditioned response, then returning the participants to Context A after extinction in Context B should not result in recovery of the conditioned behavior. Contrary to that

FIGURE 10.2. Illustration of the Renewal Effect



Note. Participants originally acquire the conditioned response in Context A. They then receive extinction training in Context B, which results in a decline of the conditioned response. In the third phase, they are returned to Context A for testing. The conditioned response is "renewed" when the participants are returned to Context A. (Data are hypothetical.)

prediction, responding is restored to a degree when the participants are returned to Context A. As with spontaneous recovery, the restoration of performance is usually not complete. However, even partial return of the conditioned response indicates that conditioned responding is "renewed" upon return to the context of original training. This is called **ABA renewal**.

A major interpretation of the renewal effect is that the memory of extinction is specific to the cues that were present during the extinction phase. Therefore, a shift away from the context of extinction disrupts retrieval of the memory of extinction, with the result that extinction performance is no longer evident. But why should this restore behavior that was characteristic of original acquisition? To account for this, one must make the additional assumption that original acquisition performance generalizes from one context to another more easily than does extinction performance. This is indeed the case. Notice that in Figure 10.2, participants responded as vigorously at the start of the extinction phase in Context B as they had at the end of the acquisition phase in Context A. This illustrates that a shift in context does not disrupt acquisition performance as much as it disrupts extinction performance.

Why is it that original acquisition is disrupted less by a change in context than extinction? Bouton (1993, 1994) suggested that contextual cues serve to disambiguate the significance of a CS. This function is similar to that of semantic context in disambiguating the meaning of a word. Consider the word *cut. Cut* could refer to the physical procedure of creating two or more pieces, as in "The chef cut the carrots." Alternatively, it could refer to dropping a player from a team, as in "Johnny was cut from the team after the first game." The meaning of the word *cut* depends on the semantic context.

Conducting excitatory conditioning and then extinction with a CS makes the CS ambiguous because the CS could signify an impending US (acquisition) or the absence of the US (extinction). This ambiguity makes the CS more susceptible to contextual control. After acquisition training alone, the CS is not ambiguous because it only signifies one thing (impending US delivery). Such a CS is therefore not as susceptible to contextual control as one that has undergone both acquisition and extinction.

One mechanism that we discussed in Chapter 5 can help explain the context specificity of extinction. Bouton (1993) suggested that the extinction context plays the role of a **negative occasion setter**, effectively suppressing the CS–US association when participants are tested in that context. When testing occurs outside that context, the negative occasion setter would be absent and only the excitatory CS–US association would be retrieved from memory. An alternative account of renewal effects in terms of the Rescorla–Wagner model is that the extinction context develops a direct inhibitory CS–US association, but this explanation remains controversial (see Bouton, 1993; Delamater & Westbrook, 2014; Polack et al., 2012).

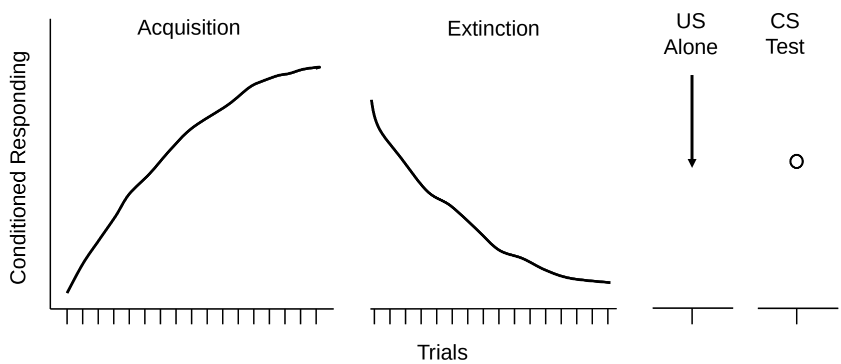
The renewal effect has important implications for behavior therapy, and unfortunately these implications are rather troubling. It suggests that even if a therapeutic procedure is effective in extinguishing a pathological fear or phobia in the relative safety of a therapist's office, the conditioned fear may return when the client encounters the fear CS in a different context. Equally problematic is the fact that the effects of excitatory conditioning can transfer from one context to another (see Figure 10.2). Thus, if you acquire a pathological fear in one situation, that fear may plague you in other places. But if you overcome your fear in a particular environment or context, this benefit will not generalize as readily. The renewal effect suggests that problems created by conditioning may be more widespread than the solutions or remedies for those problems. (For further discussion of the implications of the renewal effect for behavior therapy, see Bouton, 2014.)

Reinstatement of Conditioned Excitation

Another procedure that serves to restore responding to an extinguished CS is to expose the participant again to the US. US-induced recovery of responding to the CS is called **reinstatement**, and it is illustrated in Figure 10.3. The first phase involves CS–US pairings, which result in acquisition of a Pavlovian conditioned response. This is followed by CS-alone presentations and extinction of the conditioned response. Once the response has declined in extinction, the participant is exposed to the US by itself. This US-alone presentation results in recovery of excitatory responding to the CS.

Consider, for example, learning an aversion to shrimp cocktail because you got sick on a trip after eating some shrimp cocktail. Your aversion is then extinguished by nibbling shrimp without getting sick on several occasions. In fact, you may actually regain your enjoyment of shrimp cocktail because of this extinction experience. The phenomenon of reinstatement suggests that if at that point you were to become sick again for some unrelated reason, your aversion to shrimp would return. (For an analogous study with laboratory rats, see Schachtman et al., 1985.) Notice that reinstatement of an extinguished response is caused by presentation of the US by itself, not pairing of the CS with the US.

FIGURE 10.3. Illustration of the Reinstatement Effect



Note. After acquisition and extinction training, subjects receive exposures to the US alone. This is then followed by tests of responding to the CS. The US-alone presentation produces recovery in responding to the CS. (Data are hypothetical.)

As with renewal, reinstatement is a troublesome phenomenon for behavior therapy. Behavior therapy often involves trying to get clients to stop doing things that are counterproductive for them. Extinction is an effective technique for reducing behavior. However, because of reinstatement, responses that are successfully extinguished during the course of a therapeutic intervention can recur if the individual encounters the US again. For example, reinstatement has been developed as a model for relapse after treatment for drug addiction (Bossert et al., 2013). Drug addiction treatment typically includes an extinction component that serves to reduce the power of cues that elicit drug cravings. Extinguishing these cues also reduces instrumental responses involved in the procurement and consumption of the drug. However, a “free” encounter with the drug can reverse these therapeutic gains through the phenomenon of reinstatement.

ENHANCING EXTINCTION PERFORMANCE

The phenomena of spontaneous recovery, renewal, and reinstatement show that conditioned responding is not totally eliminated by extinction procedures. Although there is evidence that extinction produces some loss of associative strength (Delamater et al., 2021), enough of the original learning remains to allow for the various types of recovery effects that we have considered. For example, extinction procedures do not eliminate S–O and R–O associations (Delamater, 2012a; Rescorla, 1993). Given the significance of extinction for behavior therapy, an important area of contemporary research is to find ways of enhancing the response inhibition that is created by extinction procedures.

A relatively simple strategy for enhancing extinction is to increase the number of extinction trials. Conducting more extinction trials produces stronger suppression of conditioned behavior in a variety of learning situations (e.g., Leung et al., 2007). However, a related variable, the interval between successive extinction trials, is also important. Both basic and applied research has shown that increasing the intertrial interval in extinction reduces spontaneous recovery and thereby produces more enduring suppression of conditioned behavior (Tsao & Craske, 2000; Urcelay et al., 2009).

Another procedure that helps to reduce recovery (or relapse) from extinction is to conduct extinction in a variety of contexts. This procedure is particularly effective in reducing the renewal effect. The renewal effect reflects the context specificity of extinction: extinguished responding reappears when participants are moved from the extinction context to someplace else. By conducting extinction in several contexts (or locations), extinction performance becomes less specific to the context of extinction training. As with the trial-spacing effect, the effectiveness of reducing renewal by conducting extinction in multiple contexts has been confirmed in research with both laboratory animals and human participants (e.g., Bandarian Balooch & Neumann, 2011; Thomas et al., 2009). Of particular interest for therapeutic interventions is the successful use of virtual reality to conduct extinction in multiple contexts (Dunsmoor et al., 2014).

A third strategy for enhancing extinction performance is suggested by a memory retrieval analysis. Individuals who have experienced both acquisition and extinction have competing memories guiding their behavior. The memory of acquisition encourages conditioned responding, whereas the memory of extinction discourages responding. This analysis suggests that extinction performance may be enhanced by providing reminder cues for extinction (Laborda & Miller, 2012). A tone or a light that is present only during extinction trials can come to serve as a reminder cue for extinction. Presenting such a stimulus can then be used to activate the memory of extinction.

Presenting a reminder cue for extinction has been found to reduce spontaneous recovery and the renewal effect in a variety of experimental situations (Brooks, 2000; Nieto et al., 2020). Reminder cues for extinction have also been found to enhance the effectiveness of exposure therapy. For example, in a study of exposure therapy for fear of spiders, participants who were encouraged to think about the treatment context showed much less fear in novel situations than participants who did not receive this memory activation instruction (Mystkowski et al., 2006).

The fourth and final strategy for enhancing extinction that we consider involves compounding of extinction stimuli. As we noted earlier, a major driving force in extinction is the unexpected absence of the US or the reinforcer when an extinction procedure is introduced. Making the surprising omission of the US greater should produce a larger extinction effect. How can we make the absence of the US more surprising?

A clue is provided by the overexpectation experiment that we discussed in Chapter 6 (see Figure 6.4). In that experiment, two stimuli, A and B, were first conditioned with the same US, one pellet of food. The two stimuli were then presented together, followed by the same single pellet of food. Presenting A and B together created an overexpectation of food. Because stimuli A and B each predicted one pellet of food, when A and B were presented simultaneously, they predicted more than one food pellet.

Consider, then, what might be the reaction if stimuli A and B were presented simultaneously in an extinction procedure. The overexpectation of food that occurs when A and B are presented simultaneously would create an exaggerated surprise (in this case, disappointment) when food is omitted during extinction. Thus, the surprisingness of omitting the US can be increased by compounding extinction stimuli. This prediction has been confirmed in research with both laboratory animals (e.g., Leung et al., 2012; Rescorla, 2006) and human participants (Coelho et al., 2015; Lancaster et al., 2020).

"PARADOXICAL" REWARD EFFECTS IN EXTINCTION

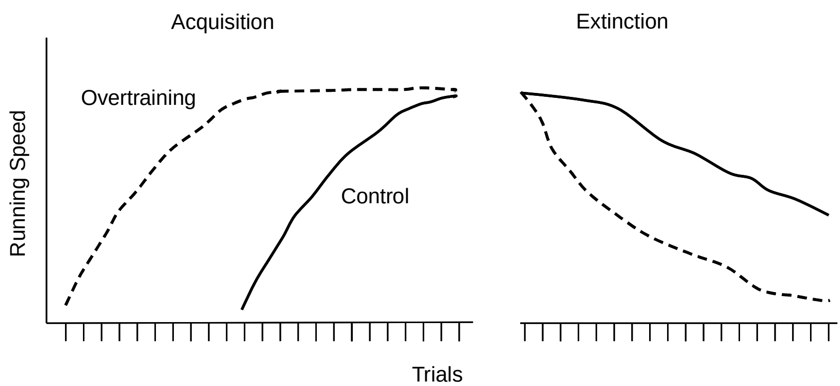
We turn next to considering several extinction phenomena that have been called **paradoxical reward effects**. These phenomena are paradoxical because they are counterintuitive—not what you would predict ahead of time. However, as we will see, each of these effects makes sense if you consider the role of frustration in extinction. Frustration is aversive and could be a component of extinction learning that promotes the suppression of conditioned responding (Rescorla, 2001). Paradoxical reward effects were originally investigated in straight-alley runway experiments with rats. They do not command much attention in contemporary research, but they are common in daily experience and are important to consider in applications of reinforcement principles in various settings (e.g., childrearing).

Overtraining Extinction Effect

One of the paradoxical reward effects involves the impact of extensive reinforced training on subsequent extinction. Thinking casually, one might suppose that more extensive reinforcement training would create a "stronger" response that is more resistant to extinction. But, in fact, the opposite can be the case, especially when training involves continuous reinforcement. The more accustomed you become to receiving reinforcement, the more rapidly you will give up in the face of nonreinforcement.

Providing more training with continuous reinforcement increases the expectation of reward. Because of this, when extinction is introduced, the frustrative effects of nonreinforcement will also be greater. Because the decline in responding in extinction is due to the frustrative effects of nonreward, more extensive reinforcement training produces more rapid extinction. This result, illustrated in Figure 10.4, is called the **overtraining extinction effect** (Ishida & Papini, 1997). The overtraining extinction effect is "paradoxical" because it involves fewer responses in extinction after more extensive reinforcement training.

FIGURE 10.4. Illustration of the Overtraining Extinction Effect



Note. During acquisition, two groups receive continuous reinforcement for performing an instrumental response. The overtraining group is trained until it reaches asymptote, and then training continues for additional trials. In contrast, the control group is trained only until it reaches asymptote. Both groups then receive extinction trials. Responding declines more rapidly for the overtrained group than for the control group. (Data are hypothetical.)

Magnitude of Reinforcement Extinction Effect

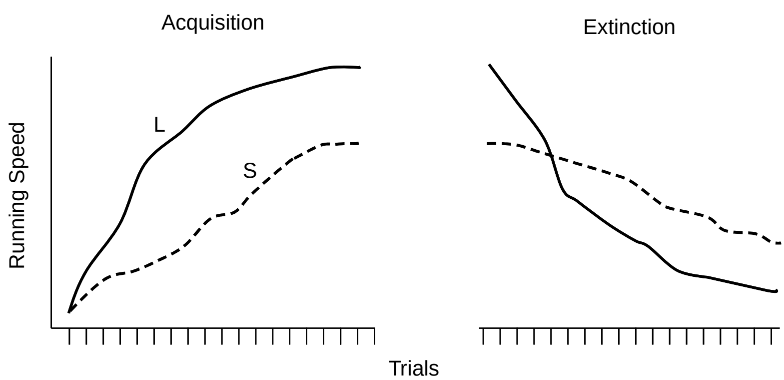
Another paradoxical reward effect that reflects similar mechanisms is the **magnitude-of-reinforcement extinction effect.** This phenomenon reflects the fact that responding declines more rapidly in extinction after reinforcement with a larger reinforcer (see Figure 10.5), especially if training involves continuous reinforcement (Hulse, 1958; Wagner, 1961). The magnitude-of-reinforcement extinction effect is also readily accounted for in terms of the frustrative effects of nonreward. Nonreinforcement will be more frustrating if the individual has come to expect a large reward than a small reward. Consider two scenarios: In one, you receive $300 per month from your parents to help with incidental expenses at college; in the other, you receive only $50 per month. In both cases, your parents stop the payments when you drop out of school for a semester. This nonreinforcement will be more aversive if you had come to expect the larger monthly allowance.

Thinking casually, one might predict that providing a larger reinforcer for each occurrence of the instrumental response will create stronger learning and therefore will produce more persistent responding in extinction. The magnitude of reinforcement extinction effect tells us that the outcome will be just the opposite. Increasing the size and frequency of the reinforcer leads participants to give up trying more quickly when they encounter failure or nonreinforcement. As with the overtraining extinction effect, the magnitude of reinforcement extinction effect is more prominent following continuous rather than intermittent reinforcement and has been studied more commonly in runway experiments.

Partial Reinforcement Extinction Effect

A key factor that determines the vigor of both the behavioral and the emotional effects of an extinction procedure is the schedule of reinforcement that

FIGURE 10.5. Illustration of the Magnitude-of-Reinforcement Extinction Effect

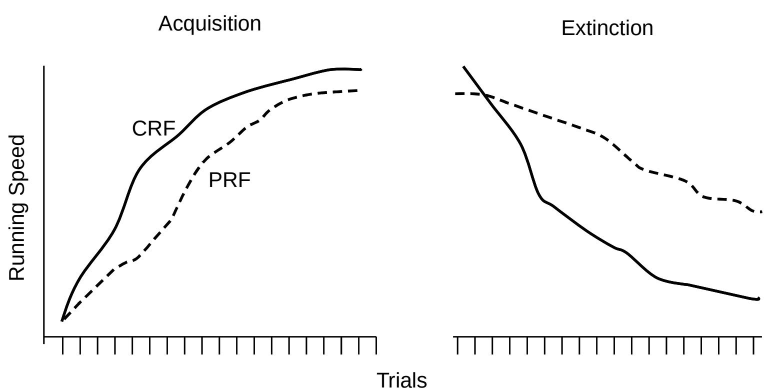


Note. During the acquisition phase, one group of subjects is reinforced (on a continuous-reinforcement schedule) with a small reward (S), while another group is reinforced with a large reward (L). Both groups then receive extinction training. During the extinction phase, responding declines faster for group L than for group S. (Data are hypothetical.)

is in effect before extinction is introduced. Various subtle features of reinforcement schedules can influence the persistence of the behavior during extinction. However, the dominant schedule characteristic that determines extinction effects is whether the instrumental response is reinforced every time it occurs, called **continuous reinforcement**, or only some of the times it occurs, called **intermittent reinforcement** or **partial reinforcement**. The general finding is that extinction is much slower and involves fewer frustration reactions if partial reinforcement rather than continuous reinforcement was in effect before introduction of the extinction procedure (see Figure 10.6). This phenomenon is called the **partial-reinforcement extinction effect** or PREE. The PREE is the most extensively investigated paradoxical reward effect (e.g., Harris, Kwok, & Gottlieb, 2019).

The persistence in responding that is created by intermittent reinforcement can be remarkable. Habitual gamblers are slaves to intermittent reinforcement. Occasional winnings encourage them to continue gambling during long strings of losses or nonreinforcement. Interestingly, in a computer-based laboratory study of instrumental responding, habitual gamblers showed greater persistence in extinction than nongamblers following partial reinforcement (Horsley et al., 2012). Intermittent reinforcement can also have undesirable consequences in parenting. Consider, for example, a child riding in a grocery cart while the parent is shopping. The child asks the parent to buy a piece of candy. The parent says no. The child asks again and again and then begins to throw a temper tantrum because the parent continues to say no. At this point, the parent is likely to give in to avoid public embarrassment. By finally buying the candy, the parent will have provided intermittent reinforcement for the repeated demands for candy. The parent will also have reinforced the tantrum behavior. The intermittent reinforcement of the requests for candy will increase the child's persistence in asking for candy during future shopping trips.

FIGURE 10.6. Illustration of the Partial-Reinforcement Extinction Effect



Note. During the acquisition phase, one group of subjects receives continuous reinforcement (CRF), while another group receives partial or intermittent reinforcement (PRF). Both groups then receive extinction training. During the extinction phase, responding declines faster for the CRF group than for the PRF group. (Data are hypothetical.)

Mechanisms of the Partial Reinforcement Extinction Effect

Perhaps the most obvious explanation for the partial-reinforcement extinction effect is that the introduction of extinction is easier to detect after continuous reinforcement than after partial reinforcement. If you don't receive the reinforcer after each response during training, you may not immediately notice when reinforcers are omitted altogether during extinction. The absence of reinforcement is presumably much easier to detect after continuous reinforcement. This explanation of the PREE is called the **discrimination hypothesis**.

Although the discrimination hypothesis makes sense intuitively, the partial-reinforcement extinction effect is not so straightforward. In an ingenious test of the discrimination hypothesis, Jenkins (1962) and Theios (1962) first trained one group of animals with partial reinforcement and another with continuous reinforcement. Both groups then received a phase of continuous reinforcement before extinction was introduced (see Table 10.1). Because the extinction procedure was introduced immediately after continuous-reinforcement training for both groups, extinction should have been equally noticeable or discriminable for both. However, participants who initially received partial-reinforcement training were slower to extinguish their behavior. These results indicate that the response persistence produced by partial reinforcement does not come from greater difficulty in detecting the start of extinction (see also Harris, Seet, & Kwok, 2019). Rather, it seems that participants learn something long-lasting from partial reinforcement that is carried over through a phase of continuous reinforcement. Partial reinforcement seems to teach participants not to give up in the face of failure, and this learned persistence is retained even if they subsequently experience an unbroken string of successes.

What do participants learn during partial reinforcement that makes them more persistent in the face of a run of bad luck or failure? Numerous complicated experiments have been performed to answer this question. These studies indicate that partial reinforcement promotes persistence in two ways. One explanation, frustration theory, is based on what individuals learn about the emotional effects of nonreward during partial-reinforcement training. The other explanation, sequential theory, is based on what individuals learn about the memory of nonreward.

Frustration Theory

According to **frustration theory**, persistence in extinction results from learning something unusual, namely, to continue responding when you expect to be

TABLE 10.1. Design of the Jenkins/Theios Experiment to Test the Discrimination Hypothesis

Phase 1	Phase 2	Phase 3
PRF	CRF	Extinction result: Slow extinction
CRF	CRF	Extinction result: Rapid extinction

Note. PRF = partial reinforcement; CRF = continuous reinforcement.

frustrated (Amsel, 1992; Papini, 2003). The expectation of frustration becomes a cue for responding during the course of partial reinforcement training. Because frustration is not experienced with continuous reinforcement training, CRF training does not create that type of persistence. How the expectation of frustration becomes a cue for responding with PRF training is a bit complicated.

Partial reinforcement involves both rewarded and nonrewarded trials. On rewarded trials you learn to expect reward; on nonrewarded trials you learn to expect frustration. With sufficient training, both of these expectations become activated at the start of each trial. In the typical partial-reinforcement schedule, reinforcement is not predictable. Therefore, the instrumental response ends up being reinforced on some of the trials when the participant expects to be frustrated. As a result of such episodes, the instrumental response becomes conditioned to the expectation of frustration. According to frustration theory, this is the key to persistent responding. In a sense, intermittent reinforcement teaches us to keep going in the face of anticipated failure. Once the response has become conditioned to the expectation of frustration, responding persists when extinction is introduced.

By contrast, nothing about the experience of continuous reinforcement encourages individuals to respond when they expect frustration. With continuous reinforcement, one only learns to expect reward, so frustration never gets associated with responding. Continuous reinforcement does not teach us what to do when we expect to be frustrated; therefore, we are more likely to quit when we experience frustration during extinction.

Sequential Theory

According to **sequential theory**, which was proposed by Capaldi (1967, 1971), individuals can remember whether or not they were reinforced for performing the instrumental response in the recent past. They remember both recently rewarded and recently nonrewarded trials. The theory further assumes that during intermittent reinforcement training, the memory of nonreward becomes a cue for performing the instrumental response. According to sequential theory, this produces persistence in extinction. Precisely how this happens depends a great deal on the sequence of rewarded (R) and nonrewarded (N) trials that are administered in the intermittent reinforcement schedule. This is why the theory is labeled "sequential."

Consider the following sequence of trials: RNN<u>R</u>RN<u>R</u>. In this sequence the participant is rewarded on the first trial, not rewarded on the next two trials, then rewarded twice, then not rewarded, and then rewarded again. The fourth and last trials are critical in this schedule and are therefore underlined. On the fourth trial, the participant is reinforced after receiving nonreward on the two preceding trials. It is assumed that the participant remembers the two nonrewarded trials when it is reinforced on the fourth trial. Because of this, the memory of two nonrewarded trials becomes a cue for responding. Responding in the face of the memory of nonreward is again reinforced on the last trial. On this trial, the participant is reinforced for responding during the memory of one nonrewarded trial. After enough experiences like these, the individual learns to respond whenever it remembers not having gotten reinforced on the preceding trials. This learning creates persistence of the instrumental response in extinction.

Some have regarded frustration theory and sequential theory as competing explanations of the partial-reinforcement extinction effect. Since the two mechanisms were originally proposed, however, a large and impressive body of evidence has been obtained in support of each theory. Therefore, it is inappropriate to regard one theory as correct and the other as incorrect. It is interesting to realize that both theories are based on the role of S-R associations in motivating behavior. In frustration theory, S is the expectancy of frustration, whereas in sequential theory S is the memory of nonreward. Both of these S-R associations promote responding in extinction, but for different reasons.

Persistence of responding in extinction is considered a poor outcome in behavior therapy where the goal is to suppress maladaptive responses. However, persistence in the face of nonreinforcement is an enviable trait in many other areas of life. Professional baseball players have to continue swinging at pitches even though they successfully hit the ball less than a third of the time. Success in business, science, and politics often comes from persistence in the face of repeated failures.

SUMMARY

Reinforcement procedures are not always permanent. The study of extinction tells us what happens when a response is no longer reinforced or a CS is no longer paired with a US. Extinction produces two prominent behavioral changes: a decrease in the conditioned response and an increase in response variability. These changes depend on the previous circumstances of reinforcement. Overtraining and the use of a larger reinforcer produce faster decreases in responding during extinction, especially with continuous reinforcement. In contrast, partial or intermittent reinforcement slows the response decline.

The decrease in responding that occurs with extinction is highly context specific and looks like the opposite of acquisition, but unlearning is just one of many mechanisms of extinction. Extinction also involves learning to suppress the conditioned behavior through various processes including the learning of an inhibitory S-R association, learning to anticipate the frustrative effects of nonreward, learning not to attend to a nonreinforced CS, and learning hierarchical negative occasion setting associations. The phenomena of spontaneous recovery, renewal, and reinstatement illustrate that extinction is at least partially reversible. However, extinction effects can be enhanced with repetitions of the extinction procedure, spacing of extinction trials, conducting extinction in multiple contexts, providing cues that reactivate the memory of extinction, and compounding extinction stimuli.

SUGGESTED READINGS

Bouton, M. E. (2014). Why behavior change is difficult to sustain. *Preventive Medicine*, *68*, 29–36.

Bouton, M. E., Maren, S., & McNally, G. P. (2021). Behavioral and neurobiological mechanisms of Pavlovian and instrumental extinction learning. *Physiological Reviews*, *101*(2), 611–681. https://doi.org/10.1152/physrev.00016.2020

Coelho, C. A., Dunsmoor, J. E., & Phelps, E. A. (2015). Compound stimulus extinction reduces spontaneous recovery in humans. *Learning & Memory*, *22*(12), 589–593. https://doi.org/10.1101/lm.039479.115

Namkung, H., Thomas, K. L., Hall, J., & Sawa, A. (2022). Parsing neural circuits of fear learning and extinction across basic and clinical neuroscience: Towards better translation. *Neuroscience and Biobehavioral Reviews*, *134*, Article 104502. https://doi.org/10.1016/j.neubiorev.2021.12.025

TECHNICAL TERMS

extinction, page 156
forgetting, page 156
frustration, page 156
inhibitory S–R association, page 158
spontaneous recovery, page 159
renewal, page 159
ABA renewal, page 161
negative occasion setter, page 161
reinstatement, page 162
paradoxical reward effect, page 164
overtraining extinction effect, page 165
magnitude-of-reinforcement extinction effect, page 166
continuous reinforcement, page 167
intermittent reinforcement, page 167
partial reinforcement, page 167
partial-reinforcement extinction effect, page 167
discrimination hypothesis, page 168
frustration theory, page 169
sequential theory, page 169

For chapter summaries and practice quizzes, visit https://www.apa.org/pubs/books/essentials-conditioning-learning-fifth-edition (see the Student Resources tab).