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A Review of the Empirical Laws of Basic Learning in Pavlovian Conditioning

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Contemporary learning research has provided multiple paradigms that have benefited not only researchers in the field, but also applied theorists and practitioners. However, the emphasis on theory development has made the learning literature almost impenetrable to nonexperts. In the present paper, we attempt to summarize not the different theoretical perspectives that have been proposed to explain different instances of learning, but the empirical relationships that testing of such theories has uncovered. Because the empirical relationships we summarize here hold across preparations and species, we suggest that such relationships should be understood as the *empirical laws of basic learning*. The focus of our review is the Pavlovian conditioning tradition, but most of these relationships also apply to instrumental learning and causality learning. We hope that the relatively novel organization we present here helps researchers and practitioners to directly incorporate these empirical principles into their current theoretical framework, whatever it may be.

The study of behavioral change can be traced as far back as civilization itself. The works of Aristotle, Plato, Kant, and Hume (among others) reflect the philosophical roots of the study of behavior change. However, the rigorous scientific study of behavioral change started only about 120 years ago with the work of Ebbinghaus (1885/1913), Thorndike (1898), and Pavlov (1927), among others. These early scientific endeavors were largely driven by empirical phenomena, although theorizing was also evident. For example, Pavlov suggested that different stimuli were represented as “centers” in the brain, which were linked either by nature (as in the case of an unconditioned stimulus, US, and an unconditioned response, UR) or by experience (as in the case of a conditioned stimulus, CS, and a US). Similarly, Thorndike’s (1911) Strong Law of Effect posited that there is no learning without reinforcement because reinforcers are required to engage the learning mechanism.

A problem with these theoretical interpretations was that many researchers viewed Pavlov’s and Thorndike’s *theoretical accounts* as *definitions* of learning. Thus, Pavlov’s stimulus substitution view cemented the belief that, in classical conditioning, learning occurs only if the US can elicit a response without learning, overlooking phenomena such as second-order conditioning (e.g., Pavlov, 1927) and sensory preconditioning (Brogden, 1939; see below). Similarly, Thorndike’s (1911) Strong Law of Effect cemented the belief that no learning could occur in the absence of reinforcement, which obviates situations in which learning occurs without apparent shifted reinforcement (e.g., song learning by birds). Thus, on many occasions, the focus from the

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empirical phenomenon to the theoretical explanation of it. In part as a reaction to this problem, Skinner (e.g., 1938, 1950) stressed the importance of identifying empirical relationships without constraining the interpretation of the data by a preexisting theory. We view both the theory-bound and the antitheoretical perspectives as extremes, and we opt for an intermediate position. Theoretical developments are essential for the advancement of psychological science. Without theory, research would have no direction and there would be no opportunity to integrate disparate observations into a common framework (Platt, 1964; Popper, 1959). However, it is critical that we not confuse theory with empirical observations. Psychological theories come and go, but the empirical relationships that they must explain remain. That is, we must distinguish between *empirical* phenomena (i.e., *data* observed in the laboratory) and theoretical accounts of what has been observed (i.e., attempts to *explain* the empirical observations).

Here, we attempt to summarize the empirical relationships that appear to be robust and generalize most widely across tasks and species, avoiding theoretical interpretations where possible. With this goal in mind, phenomena are organized according to similarity of treatments and their effects on behavior rather than on presumed underlying mechanisms. In the present paper, *learning* will not refer to the [cognitive or neural] processes that underlie behavioral change, but rather to the behavioral change that is observed as a result of the training experience. We will draw our laws of learning mostly from the classical (i.e., Pavlovian) learning literature, which refers to behavioral change induced by contingencies between cues and outcomes. However, most of what we have to say readily translates into instrumental and causality learning situations (see below).

As a final note, the review presented here is intended to be informative, not exhaustive. Readers interested in a more in-depth review of the empirical laws that we describe here can find such a review in Miller and Escobar (2002).

Stimulus Salience

Salience is often used to refer to a variable that depends upon both the state of the subject and the physical characteristics of the stimulus (i.e., cue or outcome) in question. Here we concentrate on how *stimulus salience*, understood exclusively in terms of the attributes of the stimulus, affects the acquisition of behavior. The salience of a cue generally is positively correlated with how fast conditioned responding is acquired (i.e., it influences the *rate of acquisition*; Kamin, 1965), and the salience of the outcome is generally positively correlated with how much conditioned responding is observed (i.e., it influences the *asymptotic magnitude* or probability of conditioned responding; e.g., Kimble, 1955). Simply stated, more salient stimuli promote faster learning and more conditioned responding than less salient stimuli. The best known determinant of stimulus salience is surely intensity, but other determinants of stimulus salience include stimulus size, motion, contrast, and stimulus change, among others. Importantly, stimulus salience has facilitative impact on behavior not only during training, but also during testing (cf. Hull, 1952; e.g., Kamin, 1965).

Similarity and Contiguity

Some of the 18th century British empiricists (e.g., Berkeley, 1710/1946) correctly recognized the importance to learning of stimulus similarity. If the cue and outcome share some attributes, learning will occur faster than if they do not share any attributes (e.g., Rescorla & Furrow, 1977). For example, two lights or two tones are more readily associated than a light and a tone; however, it is unclear whether this facilitatory effect arises from stimulus generalization between the cue and outcome and/or enhancement of the effects of the pairings. Stimulus similarity is defined not only with respect to the *what* aspects of the stimuli (i.e., modality, size, shape, texture, etc.), but also with respect to their *where* (space) and *when* (time). Thus, contiguity in space and time might be viewed as special instances of stimulus similarity. Despite there being some compelling demonstrations of the importance of stimulus similarity for associative learning (e.g., Krane & Wagner, 1975; Rescorla & Furrow, 1977; Testa, 1975), the importance of stimulus similarity for learning in dimensions other than time and space has not been sufficiently emphasized in recent years.

In general terms, contiguity between the cue and the outcome favor the development of conditioned responding. The effects of contiguity are observed in both the temporal domain (Pavlov, 1927) and the spatial domain (Rescorla & Cunningham, 1979). Temporal contiguity has received the most attention in learning research, with some theorists proposing that it should be considered a sufficient condition for learning to occur (e.g., Estes, 1950; Guthrie, 1935). However, despite contiguity being maximal when the cue and outcome occur simultaneously, the usual observation is that behavioral control by the cue-outcome relationship appears to be stronger if the cue immediately precedes the outcome during training, or even if a small interval separates termination of the cue from the onset of the outcome, than if they are simultaneous. We will address this *simultaneous conditioning deficit* below.

One must note that the effects of contiguity vary depending on the stimuli and preparations used to assess the acquisition of new behavior. For example, in eyelid conditioning, conditioned responding occurs only when the interval between onset of the cue and onset of the outcome is less than 1 s (e.g., Kimble, 1947; McAllister, 1953). In contrast, in conditioned taste aversion training, conditioned responding occurs even if several hours separate the taste and toxin (e.g., Garcia, Ervin, & Koelling, 1966). Despite these differences, in all cases the relationship between cue-outcome intervals and amount of conditioned responding follows the same function: As the interval increases from zero, conditioned responding briefly increases until a most effective interval is reached, and then it smoothly decreases until a complete absence of responding is reached.

Sufficiency of Contiguity

The sufficiency of contiguity for the development associative learning requires little consideration because of the many situations in which learning does not occur despite the cue and outcome being contiguous. For example, if the cue is of very low salience, learning will be weak despite strong contiguity. Similarly, variations in cue-outcome contingency (discussed below) can override the effects of contiguity. Like high stimulus salience, all of the factors on this list are included because they were found to influence learning; thus, contiguity by itself is in no sense of the word “sufficient.”

Necessity of Contiguity and Mediation

Conditioned responding to a target stimulus, X, not only reflects the associative history of X. Instead, it reflects the associative history of both X and other cues associated with X. That is, conditioned responding to X can be *mediated* by another stimulus, M. Pavlov (1927) observed that a stimulus that elicits a conditioned response could be in turn used to train a conditioned response to another stimulus. Thus, in *second-order conditioning*, mediating Stimulus M is paired with the outcome (M-outcome) with the usual observation that M comes to elicit a conditioned response. Subsequently, the target cue, X, is paired with M (i.e., X-M), which acts as a surrogate US. This type of training often results in conditioned responding to Cue X. A closely related phenomenon is *sensory preconditioning* (Brogden, 1959). In sensory preconditioning, the mediating stimulus, M, and the target cue, X, are paired before M is paired with the outcome (i.e., M-outcome). This treatment often results in conditioned responding to X. Second-order conditioning and sensory preconditioning differ principally in the order in which the X-M and M-outcome pairings are given to the subject (M-outcome then X-M in second-order conditioning, and X-M then M-outcome in sensory preconditioning). The same type of mediated learning (i.e., conditioned responding to Cue X even when it has not been paired with the outcome) can also be produced when the X-M and M-outcome training trials are interspersed (e.g., Rashotte, 1981; Yin, Barnet, & Miller, 1994).

Complicating the phenomenon of mediated learning is that there appears to be two opposing types of mediation, which we shall call positive and negative. The previously mentioned phenomena of sensory preconditioning and second-order conditioning are two examples of *positive mediated responding*, in which conditioned responding to the target (X) varies directly with responding to the mediating stimulus (M). In contrast, in *negative mediated responding*, conditioned responding to the target (X) varies inversely with responding to the mediating stimulus (M). That is, if a manipulation increases (or decreases) conditioned responding to the mediating stimulus, responding to the target decreases (or increases). The best known example of negative mediation is *conditioned inhibition* (for reviews, see LoLordo & Fairless, 1981; Rescorla, 1969; Savastano et al., 1999), which might be viewed as the learning of a relationship between a cue and the omission of the outcome. There are many training procedures that result in the development of conditioned inhibition, but perhaps the best known is Pavlov's (1927) procedure, in which pairings of the target cue (X) and mediating (M) stimuli (i.e., X-M) are interspersed with pairings of the mediating stimulus and the outcome (M-outcome). After this training, subjects presented with X behave as if X predicts the omission of the outcome (e.g., subjects withdraw from a conditioned inhibitor for food; Wasserman, Franklin, & Hearst, 1974).

Note the similarity between the procedures used to obtain positive and negative mediation: In both cases, there are X-M pairings and M-outcome pairings. Recent research suggests that that the number of pairings of the target cue and mediating stimulus (i.e., X-M pairings) is at least one critical factor in determining whether positive or negative mediation will be observed. In general, few target cue-mediating stimulus pairings results in behavior consistent with positive mediation (i.e., second-order conditioning), but the behavior becomes consistent with negative mediation as the number of pairings increases (i.e., conditioned inhibition; e.g., Rashotte, 1981; Yin et al., 1994).

Relativity of Contiguity

The influence on learning of cue-outcome temporal contiguity is not absolute. Rather, it appears to be relative to the interval between successive outcomes (i.e., inter-trial interval; see Gibbon et al., 1977; Gibbon & Balsam, 1981). That is, although the long-term effects of training appear to be favored by short cue-outcome intervals, they appear to be hampered by short intervals between successive outcomes. This deleterious effect is called the *trial-spacing effect*: Massed cue-outcome pairings result in the rapid development of acquired responding (i.e., fewer trials are required to reach asymptote) which is then largely lost over long retention intervals, whereas spaced cue-outcome pairings result in the slower development of acquired responding (i.e., more trials are required to reach asymptote) which is better maintained over long retention intervals (for examples with humans, see Cook 1934; Hovland, 1940). The implications for education and skill training are as follows: Learned materials will be available to the subject for longer periods of time if practice of such material is distributed over time. In contrast, fast learning of material that need not be remembered over long periods of time will benefit from massed practice. Clearly, the desirability of spaced training trials relative to massed ones depends upon one's goals in terms of number of training trials, temporal duration of training, and retention interval. But, what if the goal is to acquire material quickly and maintain it for a long time? Landauer and Bjork (1978; also see Bjork, 1988) demonstrated that the best strategy to insure fast learning and long-term retention is to combine the two forms of trial spacing. Landauer and Bjork asked subjects to imagine that they were at a cocktail party and they were to learn the names of several people they met at that party. The names were presented in a massed schedule, a spaced schedule, or an expanding schedule (in the latter schedule, the intertrial interval increased with repeated trials). Their results suggested that the expanding schedule was the optimal strategy: Seemingly, massing in the first few trials enhanced recall in the immediate subsequent trials, and spacing in later trials enhanced long-term recall of the learned material.

Decomposing Stimuli as a Function of Time

There is abundant evidence that subjects perceive a stimulus as a series of elements, using not only stimulus onset as a cue for behavior, but also stimulus presence (often with respect to time since onset; e.g., Romaniuk & Williams, 2000) and stimulus termination. Yet, for all stimulus components (e.g., stimulus onset, each instant of stimulus presentation, and stimulus termination), proximity to the outcome appears to determine the degree to which the learned behavior will be exhibited. For example, animals trained with a long auditory signal of shock will not exhibit fear-related behaviors until the last few seconds of presentation of the cue (i.e., inhibition of delay, cf. Pavlov, 1927; Rescorla, 1967). Thus, decomposition of stimuli into component parts complicates analysis, but does not appear to compromise the importance of contiguity for the occurrence of learning.

Spatial Contiguity

Today we recognize that spatial contiguity, as well as temporal contiguity, is an important determinant of learning. All other things being equal, cues and outcomes that occur close in space become better associated than cues and outcomes that occur far apart from each other. For example, Rescorla and Cunningham (1979) trained pigeons with a pair of events. With identical temporal relationships, in one group the two events occurred in the same spatial location, whereas in the other group the two events occurred in different spatial locations. Although pigeons in both groups acquired an association between the two events, the group for which the two events occurred in the same spatial location acquired the association faster than the group for which the two events occurred in different spatial locations. Thus, contiguity can be characterized as a spatiotemporal variable which impacts learning across almost all situations and parameters.

Predictive Value as an Alternative to Contiguity

We have already discussed the problem that mediated learning poses for contiguity. An even greater problem is the observation that more robust behavior control appears to occur when a cue slightly *precedes* an outcome (i.e., delay conditioning) than when the cue and outcome are simultaneously presented during training (simultaneity represents maximal contiguity). This *simultaneous conditioning deficit* suggests that contiguity may not be a necessary condition for learning to occur; indeed, it may even hamper learning. However, one must realize that most experimental situations require subjects to “anticipate” the outcome, and it would be functionally inappropriate to respond to a simultaneous cue which effectively announces that the outcome is present “now” as if it announced that “it is coming” (e.g., Matzel, Held, & Miller, 1988; Savastano & Miller, 1998). Esmoris-Arranz, Pardo-Vázquez, and Vázquez-García (2003) observed that rats freeze but fail to exhibit a flight response when trained with a delayed signal-shock relationship, and exhibit flight but not freezing responses when trained with a simultaneous signal-shock relationship. This observation is consistent with rats’ response to danger in the natural environment: Rats freeze when presented with cues that allow them to anticipate immediate danger, but vocalize and take flight when presented with cues that indicate danger in the current situation. That is, the specific form (i.e., topology) of the conditioned response changes with the temporal relationship between the cue and the outcome (e.g., Burns & Domjan, 1996; Timberlake & Lucas, 1991). Most conditioned fear preparations use freezing measures, which require rats to anticipate, rather than deal with immediate danger.

Importantly, the order in which the subject experiences the paired events also influences the behavior that is ultimately observed. For example, forward pairings (cue→outcome) usually result in excitatory conditioned responding to the cue, whereas backward pairings (outcome→cue) of the same cue and outcome initially result in weak excitatory conditioned responding to the cue, which changes to behavior consistent with conditioned inhibition with subsequent trials (e.g., Heth, 1976). Regardless of the order of the cues, neither excitatory nor inhibitory behavioral control is observed when the temporal separation of the cue and outcome exceeds a certain threshold duration (e.g., Miller et al., 1991).

Predispositions

People and other animals never enter a learning situation *tabulae rasae*. They arrive with *predispositions* that result in more rapid learning of some cue-outcome dyads than others. Probably the most cited example of such predispositions is Garcia and Koelling's (1966) "bright-noisy water" experiment. In this study, Garcia and Koelling found that rats acquired flavor aversion more rapidly when the flavor was paired with an internal malaise (induced upset stomach) than when it was paired with footshock, whereas they acquired fear of an audiovisual cue more rapidly when it was paired with the footshock than when it was paired with the internal malaise. That is, rats are more predisposed to associate ingested flavors with internal stimuli (such as stomach upset) than lights and sounds, whereas they are more predisposed to associate external painful stimuli (such as footshock) with lights and sounds than ingested flavors. Predispositions are sometimes called cue-to-consequence effects, and were anticipated by Thorndike's (1932) concept of "belongingness."

Garcia originally viewed predispositions as genetic in origin, specifically a result of natural selection in the animal's ecological niche. According to this view, animals are more prepared to learn about stimulus dyads that are functional in their natural habitat than about nonfunctional dyads. Thus, rats, which in their natural habitat find food primarily through olfactory and gustatory cues, are more predisposed to associate internal malaise with odors and tastes than with audiovisual cues. In contrast, rodents avoid potential predators mostly by using auditory cues, which is consistent with the observation that audiovisual stimulus-shock associations were favored. Similarly, humans exposed to chemotherapy or radiotherapy tend to report conditioned nausea when presented with cues associated to the chemical or radiological treatment (e.g., Stockhorst, Klosterhalfen, & Steingrueber, 1998). Moreover, conditioned nausea occurs more readily to smells and tastes than to visual cues (e.g., Cameron et al., 2001). Thus, humans too are more predisposed to associate smells and tastes than visual cues with gastrointestinal upset. However, research has made clear that prior experience interacts with genetic predispositions to determine which stimulus dyads will be favored in learning. For example, Dalrymple and Galef (1981) found that, although rats are initially slow to associate visual cues and illness, they become better at doing so after extended experience with these cue-outcome pairs (consistent with these studies, chemotherapy patients that have received extensive treatment report nausea when approaching the hospital or reading hospital signs in the highway). Thus, like all other aspects of behavior, predispositions to establish stimulus control of behavior appear to reflect an interaction of genes and prior experience.

Predispositions appear to be so embedded in the genetic makeup of subjects that learning consistent with these predispositions occurs extremely rapidly, and might even occur as a result of observing another individual interacting with the cues and outcomes. For example, Mineka and her colleagues (e.g., Mineka et al., 1984) have demonstrated that monkeys acquire conditioned fear of plastic snakes much faster than they acquire conditioned fear of plastic flowers (i.e., they are predisposed to fear snakes but not flowers). Interestingly, this difference is also observed if subjects do not directly interact with the snake or flowers, but instead merely observe a video of another monkey interacting with the snake or flower (Cook & Mineka, 1990).

By and large, humans and other species are predisposed such that most specific instances of learning are functional (i.e., they appear to serve the goals of survival and

genetic propagation). An excellent example is the influence of learning on sexual behavior. Hollis and her colleagues (e.g., Hollis, Cadieux, & Colbert, 1989) have demonstrated that Pavlovian signals of female accessibility decrease aggressive behavior in territorial fish, which in turn increases the likelihood of a successful encounter between the male and the female (see Hollis, 1997, for other examples of functional analyses of Pavlovian behavior). However, there are numerous documented examples in which specific instances of learned behavior are not functional, but instead detrimental to the well being of an organism. Typically, these instances arise in situations that create contingencies contrary to those that prevail in the animal's natural habitat or are inconsistent with its past experience. One type of dysfunctional acquired responding is illustrated in vicious circle behavior (Gwinn, 1949). Typically, in Phase 1, rats are placed in a start box and the beginning of the trial is signaled by the experimenter's lifting a barrier and delivering foot shock in the start box. Rats must then run through an electrified runway to reach a safe goal box. In Phase 2, the start box is not electrified anymore, but the animals run through the electrified runway to reach the goal box anyway, even though they could avoid shock altogether by staying in the start box. That is, their learned behavior prevents them from experiencing the new contingency (i.e., safety in the start box). A second type of dysfunctional behavior is illustrated in negative automaintenance (Williams & Williams, 1969), in which a Pavlovian conditioned response (pecking by pigeons at a cue followed by food) causes the omission of reward (food delivery), with the result that the subject keeps responding (albeit at a reduced rate) despite its pecking causing a decrease in reinforcement. This observation is not surprising if one considers that for pigeons, over many generations, pecking has been necessary to obtain food and omission of food for pecking is inconsistent with contingencies in their natural habitat.

Table 1.
2 x 2 Contingency Table for a Single Cue and Single Outcome

	Outcome present	Outcome absent
Cue present	<i>Cell a</i> # trials with cue and outcome paired	<i>Cell b</i> # trials with cue alone
Cue absent	<i>Cell c</i> # trials with outcome alone	<i>Cell d</i> # trials with cue and outcome absent

Contingency

Contingency is a term meant to convey the correlation between the cue and outcome. Contingency increases as the number of trials on which the cue and outcome are presented or omitted together increases, and it decreases as the number of trials on which either the cue or outcome are presented alone increases. Table 1 presents a *contingency table* with the four possible types of events in a learning situation: Cue-outcome pairings (Cell a), cue alone (Cell b), outcome alone (Cell c), and absence of both the cue and outcome (Cell d). In contrast with contiguity, which speaks to the quality of the cue-outcome pairings (i.e., cue-outcome spatiotemporal proximity), contingency speaks to the reliability of these pairings (independent of their contiguity). Many different algebraic formulas have been proposed to represent the impact of contingency on behavior, and each of these formulas makes assumptions about the relative values (weights) of each of the four types

of events summarized in Table 1. Research so far has failed to identify any one measure that, across tasks and parameters, consistently and accurately describes the resultant stimulus control. However, there is little argument that learning is facilitated by events that confirm a cue-outcome relationship (i.e., when the cue and outcome are paired and when neither event occurs; Cells a and of Table 1) and decremented by events that deny a cue-outcome relationship (i.e., occurrences of either the cue or outcome in the absence of the other; Cells b and c of Table 1). Learning of a cue-outcome association benefits the most from a-type (i.e., cue-outcome) trials, the least from d-type (no cue-no outcome) trials, and is intermediately impaired by b- (cue alone) and c-type (outcome alone) trials (e.g., Kao & Wasserman, 1993).

Table 2.
Attenuation of Stimulus Control by Degrading the Cue-Outcome Contingency as a Result of Adding Cue-alone or Outcome-alone Presentations

Temporal location of added event	← Added →	
	Cue	Outcome
Before cue-outcome pairings	Latent inhibition	US-preexposure effect
Interspersed during cue-outcome pairings	Partial reinforcement	Degraded contingency effect
After cue-outcome pairings	Extinction	US-postexposure effect

Note. Training here refers to cue-outcome pairings. US = an unconditioned stimulus serving as an outcome; US is used here because this procedure for degrading stimulus control has traditionally been studied in Pavlovian situations.

Degrading a contingency refers to adding presentations of the cue alone and/or the outcome alone to a situation that includes some cue-outcome pairings. The added events can occur before, interspersed among, or after the pairings, creating the six possible situations presented in Table 2. First, let us consider added cue-alone presentations. When these cue-alone presentations occur before the cue-outcome pairings, *latent inhibition* (a.k.a. the CS-preexposure effect) is often observed: If a cue has been repeatedly experienced alone, subsequent pairings of that cue with an outcome are less effective in producing a conditioned response (i.e., more pairings are required to achieve a learning criterion; Lubow & Moore, 1959). When the cue-alone presentations occur interspersed with cue-outcome pairings, we talk about *partial reinforcement*, a treatment that usually results in slower acquisition (i.e., more CS presentations to reach asymptote) and lower asymptotes of conditioned responding (Pavlov, 1927) as well as greater resistance to extinction of the conditioned response (e.g., Rescorla, 1999). Finally, if the cue-alone presentations occur after the cue-outcome pairings, we observe *extinction* (i.e., gradual dissipation) of the conditioned response (Pavlov, 1927).

Now, let us consider adding outcome-alone presentations. When these additional outcomes occur prior to the cue-outcome pairings, the resultant retardation in observing conditioned responding is called the *US-preexposure effect* (Randich & LoLordo, 1979). When outcome-alone presentations occur interspersed among the cue-outcome pairings, the resultant deficit in conditioned responding is called the *degraded contingency effect* (Rescorla, 1968). Finally, when the outcome-alone presentations occur after the pairings, the resultant deficit is sometimes called the *US-posttraining exposure effect* (hereafter

called the US-postexposure effect; Chang, Stout, & Miller, 2004), and it is the most difficult to observe of the six contingency degrading manipulations described in Table 2. Some recent studies suggest that the difficulty in obtaining US-postexposure effects is related to the so-called 'biological significance' acquired by the cue during the cue-outcome training. Miller and colleagues (e.g., Miller & Matute, 1996) have reported degraded contingency through outcome postexposure as long as the cue and outcome are of low biological relevance (i.e., neither elicits strong unconditioned responses prior to the cue-outcome pairings).

The construct of contingency is challenged by the problem of defining a trial. This problem is most evident when one tries to count the number of trials that should be counted in Cell d of Table 1: How many no cue-no outcome trials are contained in five minutes? How many in five seconds? The convention has been to define a trial as being of a fixed, uniform duration with that duration being set equal to the duration of trials on which the cue and/or outcome both occur (e.g., the duration of a typical Cell a-type trial). Such a definition is surely arbitrary, but in most cases it suffices, as long as the same duration is used to define a trial in all conditions. Of course, the entire construct of trials exists only in the mind of the experimenter: Subjects live and process information in continuous time, not in the trial-wise manner in which time is partitioned for our research purposes.

Primacy and Recency as Modulators of Contingency

Contingency degradation necessarily involves at least one of two different types of trials (i.e., the cue-outcome pairings, and either cue-alone or outcome-alone presentations). In situations in which the contingency degrading trials are not interspersed among the cue-outcome pairings (i.e., when all of one trial type precedes all of the other trial type, namely the cases of latent inhibition, extinction, US-preexposure, and US-postexposure), strong *recency* effects are observed (i.e., the resultant behavior reflects the more recent trials). For example, subjects exposed to 100 cue-outcome trials followed by 100 cue-alone trials will exhibit little conditioned responding, while if the training is reversed, robust conditioned responding will be observed. These differences in conditioned responding due to the order of trials during training are known as *trial-order effects*. Importantly, trial-order effects do not always take the form of recency effects. Sometimes, we may observe *primacy* effects, which refer to greater influence on behavior of early training experiences than later experiences. Moreover, as time elapses, recency effects often wane allowing the expression of information favored by primacy (e.g., Kraemer, Randall, & Carbary, 1991). For example, after the cue-outcome pairings, the passage of time may result in *forgetting* (i.e., a loss of conditioned responding) and, after the extinction training, the passage of time may result in *spontaneous recovery* of the extinguished conditioned response. Primacy effects are usually quite weak but, unlike recency effects, they do not wane with time alone (other manipulations, such as extinction of the context, may attenuate the effects of primacy; e.g., De la Casa & Lubow, 2002); if anything, they grow stronger with time since the end of training (see e.g., Postman, Stark, & Fraser, 1968; Underwood, 1948).

Context as a Modulator of Contingency.

As we previously stated, contingency degradation treatments necessarily involve at least two types of trials: Cue-outcome pairings to establish the contingency and which result in conditioned responding, and presentations of the cue and/or outcome alone to degrade the contingency and which attenuate conditioned responding. If the two different trial types occur in different contexts, behavior will tend to reflect the experience learned in the particular context in which the subject is currently being assessed (for a review, see Bouton, 1993)

Although we often think of *context* as referring to static background cues that persist over a [training] session, contextual cues can also be more delimited in time and space. When a discrete stimulus signals whether or not another stimulus will be followed by reinforcement, that stimulus is referred to as an *occasion setter* (Holland, 1992; Miller & Oberling, 1998); that is, a stimulus that sets the occasion for a given contingency. Research by Holland (1992) has demonstrated that an occasion setter need not elicit the conditioned response in its own right but modulates conditioned responding to the target stimulus. That is, the role of the occasion setter is to disambiguate the meaning of a target stimulus rather than to produce conditioned responding itself.

Permanence of the Degraded Contingency Effects

The loss of conditioned responding observed with all of the degraded contingency effects listed on Table 2 seems to be largely, if not entirely, a *lapse* (i.e., inaccessibility of the information), as opposed to an irreversible *loss*, of the memory of the cue-outcome pairings. We base this assertion on the observation that treatments other than further cue-outcome training can result in a return of conditioned responding. As previously mentioned, extinguished conditioned responses can spontaneously recover over long retention intervals, an observation that led Pavlov (1927) to suggest that extinction reflected new learning rather than erasure of previous learning. Spontaneous recovery from latent inhibition is also sometimes observed (Kraemer et al., 1991). Moreover, most degraded contingency effects such as latent inhibition and extinction are context dependent. That is, conditioned responding partially recovers if the subject is tested in a context in which the contingency degradation did not occur (e.g., Bouton & King, 1983; Channell & Hall, 1983). Similarly, a brief presentation of either the cue or the outcome alone often restores conditioned responding (i.e., reminder treatments; for a review see Miller, Kasprow, & Schachtman, 1985).

Interference

Since the 1960s, researchers concerned with basic animal learning have largely focused on one select type of stimulus interference, specifically how cues trained together (i.e., in compound) compete for the prediction of an outcome (i.e., cue competition). *Cue competition* refers to impaired conditioned responding to a target cue that is trained in the presence of one or more potentially competing cues. Traditionally, discussions of cue competition refer to the overshadowing and blocking effects. The *overshadowing effect* (Pavlov, 1927) refers to impaired conditioned responding to the target (overshadowed) cue due to the presence of a (usually) more salient competing (overshadowing) cue during

training with the outcome. In the *blocking effect* (Kamin, 1968), the cues are usually of equal salience, but the competing (blocking) cue receives pairings with the outcome prior to the compound trials.

Competition between cues trained together was popularized by Kamin (1968), who viewed it as having two important implications. First, it demonstrated that neither contiguity nor contingency were sufficient to support learning (until that time, the sufficiency of contiguity and contingency had been largely unchallenged). Take for example the case of overshadowing. In a typical overshadowing experiment, pairing the compound of competing Cue A and target Cue X with the outcome results in less conditioned responding to X than in a control condition in which X alone is paired with the outcome. However, the X-outcome contiguity and contingency are the same in both groups. Second, cue competition suggested to Kamin that, in situations with multiple cues, subjects do not learn about each cue in isolation; rather, the cues interact with each other to control behavior. The identification of this sort of stimulus interference greatly advanced the theoretical study of learning: Models were formulated to account for cue competition between cues that were trained together (e.g., Rescorla & Wagner, 1972). However, this focus of the models resulted in researchers' ignoring other forms of stimulus interference.

The 2 x 2 matrix in Figure 1 depicts four different types of stimulus interference. In the preceding paragraph, we discussed competition between cues trained together, which is represented by Cell 1 of Figure 1. Cell 2 is similar to Cell 1 in that it involves stimuli trained in compound but, in this case, interference occurs between outcomes trained in compound rather than between cues trained in compound. A potential problem in observing competition between outcomes is that outcomes are usually of high salience or biological relevance. Indeed, it is possible that the outcomes will be so salient that the subject will not disregard any as being related to the cue. This is the usual case with animal subjects trained with biologically significant outcomes such as food, pain, and water. The lack of interference with biologically significant outcomes should not be taken as evidence of absence of interference between outcomes. If neutral stimuli are used during training, the subject can experience both outcomes and weigh the extent to which they are predicted without the potential distraction or relevance of biologically significant outcomes. Indeed, Esmoris-Arranz, Matute, and Miller (1997; also see Miller & Matute, 1998; Rescorla, 1980, pp. 90-97) performed such studies with rat subjects and observed interference between outcomes trained together. In their study, animals were trained in a blocking preparation. Cue A (a tone) was paired with Outcome 1 (a buzzer) during the first phase of training. Then, Cue A was paired with the compound of Outcome 1 and Outcome 2 (a buzzer and a clicker, respectively). Cue A was then paired with a shock US and conditioned responding to Outcome 2 was observed to be lower than in a group which lacked the A-Outcome 1 pairings. That is, when a cue was paired with two simultaneous outcomes of low biological significance, its association with each outcome was weaker than if the cue had been paired with a single outcome.

Cell 3 depicts interference between cues trained apart with the same outcome. This paradigm was widely studied by researchers within the human verbal learning tradition in the middle of the twentieth century (for a review see e.g., Slamecka & Ceraso, 1960). In these studies, people were asked to memorize lists of word pairs, which usually shared some common terms. For example, a first list might have contained the pair cat-train and the second list might have contained the pair parrot-train. After memorizing the two lists, subjects were asked which word had previously been presented together with

the common associate (in this case, the word train). These types of studies ordinarily yielded retroactive interference (recall of the second associate, parrot) or proactive interference (recall of the first associate, cat). Cell 3-type interference is not unique to verbal materials; it has been observed with both human participants (Matute & Pineño, 1998) and rat subjects (Amundson, Escobar, & Miller, 2003; Escobar, Matute, & Miller, 2001; Escobar, Arcediano, & Miller, 2001) in nonverbal preparations. For example, Amundson et al. trained rats with pairings of auditory Cue A and a shock. Subsequently, animals were trained with pairings of a second auditory cue, X, and the shock. They observed that conditioned responding to X was lower than if the A-shock pairings had not occurred (i.e., proactive interference). Thus, we see that cue competition is not limited to cues trained in compound, but can be obtained between cues trained independently.

Cell 4 of Figure 1 describes situations in which one cue is separately paired with two different outcomes. The prototypical example of this type of interference is the phenomenon of *counterconditioning*. In a counterconditioning paradigm, a cue is first paired with Outcome 1 until that cue produces conditioned responding consistent with Outcome 1. In a subsequent phase, the cue is paired with Outcome 2, and the latter learning is observed to interfere with the original conditioned response (Pavlov, 1927; Sherrington, 1947; Wolpe, 1958). This sort of interference has also been reported in verbal learning situations with human participants (e.g., Postman, 1962) and with outcomes that do not have biological significance in rat subjects (Escobar, Arcediano, & Miller, 2001). Counterconditioning has historically been a popular method of psychotherapy (i.e., *systematic desensitization*; e.g., Wolpe, 1958), especially for the treatment of phobias and anxiety. In counterconditioning-based therapies, a stimulus (e.g., a spider) previously associated with an unpleasant emotional reaction (e.g., fear) is now associated with a pleasant emotional reaction (e.g., relaxation). Responding to the stimulus is usually a blend of the two associations, thereby reducing or eliminating the fear reaction. We must note, however, that current approaches to phobia and anxiety treatment prefer an approach different from counterconditioning. Most contemporary clinicians use *exposure therapies*, which are based on experimental extinction. In these therapies, the stimulus that elicits the unpleasant emotional reaction (in our previous example, the spider) is now presented and the client is allowed to experience the lack of an outcome (e.g., is not bitten by the spider), with the usual consequence that the unpleasant emotional reaction undergoes extinction and its intensity gradually decreases. The difference between the two approaches is that, while counterconditioning uses training with a different outcome as the therapy procedure (i.e., the therapy sessions), extinction uses training with no outcome as the therapy procedure (i.e., it degrades the contingency between the stimulus and the emotional reaction).

Types of Stimulus Interference in Basic Learning

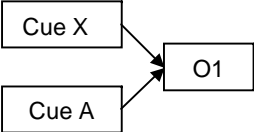
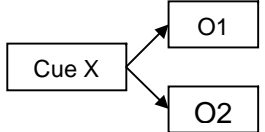
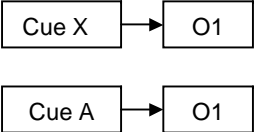
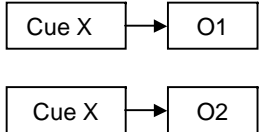
	Competing Cues	Competing Outcomes
Trained Together	<p>Cell 1:</p>  <p>Overshadowing (Pavlov, 1927): AX→O1, Test X→O1 Blocking (Kamin, 1968): A→O1, then AX→O1, Test X→O1 Relative validity (Wagner et al., 1968): AX→O1, BX→noO1, Test X→O1 Overexpectation (Rescorla, 1970): X→O1, A→O1, then XA→O1, Test X→O1</p>	<p>Cell 2:</p>  <p>Rescorla (1980) Esmoris-Arranz et al. (1997) Miller & Matute (1998) X→O1, then X→O1+O2, Test X→O2</p>
Trained Apart	<p>Cell 3:</p>  <p>Matute & Pineño (1998) Escobar, Matute, & Miller (2001) Escobar, Arcediano, & Miller (2001)</p> <p>X→O1, A→O1, Test X→O1 (RI) A→O1, X→O1, Test X→O1 (PI)</p>	<p>Cell 4:</p>  <p>X→O1, X→O2, Test X→O1 (RI) X→O2, X→O1, Test X→O1 (PI)</p> <p>Counterconditioning (Pavlov, 1927): X→US1, X→US2, Test X→US1</p>

Figure 1. A 2 x 2 matrix depicting the different types of stimulus interference that can disrupt acquired responding. In each cell, representative examples of interference procedurally appropriate for that cell are listed. ‘X’ represents the target conditioned stimulus, ‘A’ represents the interfering cue, ‘O1’ and ‘O2’ represent distinctly different outcomes, which might be unconditioned stimuli (USs) or innocuous stimuli that are later paired with USs. The bold font of the overshadowing cue in Cell 1 (denoted as ‘A’) reflects the finding that overshadowing of a target cue is greatest when the overshadowing cue is considerably more salient than the target cue. RI = retroactive interference, PI = proactive interference. Contemporary models of acquired behavior have focused almost exclusively on Cell 1 phenomena to the exclusion of phenomena in Cells 2, 3, and 4. See text for elaboration

Recency and Primacy Effects in Interference Situations

Cell 3- and Cell 4-type interference effects are also sensitive to time. Usually, if testing occurs immediately after training, subjects exhibit conditioned responding consistent with the more recent training (i.e., recency). However, this recency bias wanes as the retention interval increases, often unmasking a primacy effect (i.e., with increasing retention interval, retroactive interference decreases and proactive interference increases; e.g., Postman et al., 1968).

Interference vs. Degraded Contingency

Note that situations in which two cues are trained with one outcome (Cell 3) and situations in which one cue is trained with two outcomes (Cell 4) could be explained in terms of degradation of the cue-outcome contingency: The second stage of treatment represents a situation in which one of the elements used during the first stage of treatment is presented without the other. However, recent reports suggest that the effect of interference training is significantly greater than the effect of contingency degradation alone (Escobar, Arcediano, & Miller, 2001; Escobar, Matute, & Miller, 2001). Note that our working definition of *interference* differs from other definitions of interference (e.g., Bouton, 1993) in which interference refers to both what we here call *degraded contingency effects* and *interference effects*. Degraded contingency effects arise from presenting the cue without the outcome or presenting the outcome without the cue. Although *no-outcome* representations and *no-cue* representations may well serve as an effective associate, thereby transforming degraded contingency situations into interference situations, this is a theoretical issue that we wish to circumvent in this discussion.

Effect of Retrieval Cues

Importantly, interference has been considered one of the major sources of forgetting (e.g., McGeoch, 1932). Forgetting due to interference is usually assumed to reflect a temporary (rather than permanent) inaccessibility to the information stored in memory. This assumption is supported by the observation that several manipulations performed at the time of testing can attenuate or generate interference (e.g., Spear, 1973). For example, Escobar, Matute, and Miller (2001) trained rat subjects in an interference preparation such that retrieval of a target cue was impaired. They observed that presenting a cue that was present during training of the target cue attenuated interference and similar effects were observed by placing the animal back in the environment of target training. Conversely, presenting a cue that was present during training with the interfering cue produced interference in a situation in which no interference was otherwise observed.

Interference vs. Facilitation

We have described different types of interference as the ubiquitous effects of the four training situations described in Figure 1. However, sometimes training consistent with the four cells of Figure 1 results in *facilitation* (i.e., increased conditioned responding) rather than interference. Cell 1-type treatments sometimes result in the so-called “potentiation” effect. For example, subjects presented with the compound of a taste and

an odor followed by injection of a drug that induces internal malaise fail to exhibit competition between the two cues for prediction of the malaise. Rather, the aversion to the odor (or the taste) is increased relative to subjects that receive pairings of the odor (or taste) alone with the drug (Clarke, Westbrook, & Irwin, 1979; Rusiniak, Hankins, Garcia, & Brett, 1979; see Batsell & Batson, 1999, for a similar effect using a blocking procedure). Cell 3- and Cell 4-type treatments sometimes result in *acquired equivalence* (or *acquired similarity*), in which subjects respond to two stimuli equivalently because they were previously paired with the same outcome. For example, Honey and Hall (1989) trained two cues, A and B, as signals for a common outcome (a food pellet). Then, A was paired with shock. When B was presented at test, subjects exhibited substantial generalization of the fear conditioned response. That is, the common training history shared by A and B rendered them functionally equivalent.

Effects of Similarity on Interference

Observing stimulus interference requires that there be a certain level of similarity between the two associations (e.g., sharing a common element). However, if the two associations are identical, summation of learning rather than interference will be observed (e.g., Young, 1955). Similarly, if the two associations are completely dissimilar, exceedingly weak interference is usually observed (e.g., Escobar & Miller, 2003; Newton & Wickens, 1956).

Similarity of Training to Test Cue

Variation in the external world and inside the subject necessarily results in changes in the perceived characteristics of a stimulus over repeated presentations. Thus, it is necessary that the subject perceive slight variations of the same stimulus as instances of a previously experienced stimulus category. That is, the process of *stimulus generalization* is critical to the observation of any learning at all. In general, the maximum amount of conditioned responding is observed to the cue with which subjects were trained, and responding to other cues decreases as the similarity between them and the target cue decreases. This similarity-based decrease in conditioned responding is known as *generalization decrement* (e.g., Guttman & Kalish, 1956).

Motivation

Motivation is a complex topic with a huge literature that we could not begin to detail here. In the framework of learning, we talk about stimuli with motivational value to refer to stimuli that elicit a response because they are of either inherent biological significance (primary reinforcers; e.g., food, sex, pain) or acquired biological significance (secondary [learned] reinforcers; e.g., money, praise). A great body of research now suggests that the process of learning does not require the presence of a biologically significant stimulus; that is, learning can occur between neutral cues. Learning between neutral stimuli can be observed in both classical conditioning (sensory preconditioning; Brodgen, 1959) and instrumental conditioning (latent learning; Tolman & Honzik, 1930). However, regardless of what relationships have been *encoded* by a subject, learning is not observed unless the outcome, or an associate of the outcome, has the potential to elicit a

response in its own right. That is, motivational value of one of the associates is necessary for the *expression* of learning. For example, think of an instance of latent learning in which rats were allowed to walk through a maze without food reinforcement in the goal box. The rats show little improvement in reaching the goal box over trials, so it is not obvious that they learned about the maze. However, when food reinforcement is introduced, the rats that had previously been exposed to the maze perform better than rats that had not been allowed to interact with the maze before (Tolman & Honzik, 1930). That is, when exposed to the maze in the absence of reward, the rats *acquired* information about the maze, but they did not *express* that learning until a biologically significant stimulus entered the equation.

Extension of These Laws to Other Forms of Learning

The present review has focused on selected empirical evidence from the classical conditioning literature. However, most of the laws described here apply to other forms of learning, such as instrumental conditioning and causality learning (e.g., Allan, 1993; Miller & Balaz, 1981). Description of all the literature pertaining to these forms of learning and the laws described here would require a book. Thus, we will limit our discussion to highlighting some empirical findings to emphasize the generality of the laws we have described.

Salience of the cue and outcome are certainly known to influence instrumental performance. Of special interest are the effects of outcome salience, which can be quantified in terms of quantity and quality of the reinforcer. In general, animals respond more for larger, more palatable reinforcers (e.g., Hutt, 1954), and changes in reinforcer quantity result in marked changes in behavior (so-called *contrast effects*, e.g., Crespi, 1942). Mediation is also an issue in instrumental conditioning, as exemplified by *secondary* or *conditioned reinforcement*, in which a stimulus previously paired with a primary (i.e., biologically significant) reinforcer comes to act as a reinforcer in its own right (for discussion, see Williams, 1994). Conditioned reinforcement has also been observed in human causality judgments. For example, Reed (1999) reported that a signal presented between a response (pressing a key) and an outcome (a triangle lighting up in a computer screen) came to act as a conditioned reinforcer. Negative mediation has also been repeatedly reported in the human causality learning literature. For example, Chapman (1991) observed conditioned inhibition of causality judgments in a task in which subjects were asked to rate the likelihood that a given symptom was indicative of developing a disease.

It has been long known that delays as short as 0.5 s between the response and the outcome are known to adversely affect instrumental responding (e.g., Grice, 1948), and this deleterious effect is directly related to the length of the delay (e.g., Dickinson, Watt, & Griffiths, 1992). That is, *response-outcome contiguity* is a relevant factor in instrumental conditioning. Furthermore, consistent with the observation of inhibition of delay in Pavlovian conditioning, animals delay the onset of their instrumental responding to approximate the time of reinforcement availability (e.g., Skinner, 1938). Such exquisite timing of responding has also been observed in human conditioning (e.g., Arcediano, Escobar, & Miller, 2003).

The role of predispositions in instrumental responding has been long known. For example, Foree and LoLordo (1973, 1975) found that pigeons could more readily be trained to peck for food in the presence of a visual cue and treadle press (i.e., part of a

running response) to avoid shock in the presence of an auditory cue than with other stimulus-outcome combinations. This work parallels Garcia and Koelling's (1966) "bright-noisy water" study in Pavlovian conditioning. Thus, predispositions are observed in instrumental as well as Pavlovian situations, which was anticipated by Thorndike's (1911) concept of "readiness." Predispositions are also observed in human causality learning. For example, Bullock, Gelman, & Baillargeon (1982) have argued that humans are predisposed to acquire causal relations between events in their environment even at a young infant age. More recently, Waldmann (e.g., 2000) has argued that humans are predisposed to learn causal relations in a cause-to-effect direction, and that this direction cannot be reversed (but there are multiple detractors of this view; see e.g., López et al., 1998; Matute, Arcediano, & Miller, 1996).

The effects of contingency on instrumental reinforcement are obvious: If there is no contingency between the response and the reinforcer, instrumental responding is disrupted (i.e., extinction). *Partial reinforcement* produces one of the best-known contingency effects. Partially-reinforced behavior is more resistant to extinction than continuously-reinforced behavior (the *partial reinforcement extinction effect*). But less attention has been paid to the unsurprising but important observation that partial reinforcement usually attenuates instrumental responding (e.g., Jenkins & Stanley, 1950). Interference effects are also obvious in instrumental conditioning, although not all cells of Figure 1 have been explored. For example, Cell 1-type interference has been observed in the form of blocking (e.g., Hammerl, 1993; Roberts & Pearce, 1999). More extensive research has been performed in human causality judgments. Cell 1-type interference has been observed in blocking (e.g., Arcediano, Matute, & Miller, 1997; Arcediano, Escobar, & Matute, 2001) and overshadowing (e.g., Price & Yates, 1993). Cell 2-type interference has been observed in selected occasions (e.g., Matute, Arcediano, & Miller, 1996; Shanks & López, 1996; but see e.g., Waldmann, 2000; Waldmann & Holyoak, 1992). Cell 3- and Cell 4-type interference has been extensively reported in the human verbal learning tradition (for reviews, see e.g., Britt, 1935; Slamecka & Ceraso, 1960; Swenson, 1941), and more recently in the human causality learning literature (e.g., Escobar, Pineño, & Matute, 2002). As mentioned in the section on *Effects of Similarity on Interference*, decreased similarity between two outcomes can enhance stimulus control in select situations. For example, setting a *differential outcomes schedule*, in which different reinforcers follow each of two (or more) potential choice behaviors, results in faster discrimination than if the same reinforcer was given for both behaviors (see Overmier, Savage, & Sweeney, 1999, for a review).

Summary

Table 3 summarizes the conditions that favor the acquisition of stimulus control of behavior. These conditions are loosely ranked according to our impression of their relative importance (except Generalization and Motivation, which speak to test rather than acquisition conditions). Whether the conditions in Table 3 are viewed as influencing the expression of previously acquired relationships (Denniston, Savastano, & Miller, 2001; Miller & Matzel, 1988) or the fostering of new learning about absent stimuli (Dickinson & Burke, 1996; Van Hamme & Wasserman, 1994) is a source of current controversy in the literature.

Table 3.
Summary of the Conditions that Favor Learning.

Condition	Effect on learning
Stimulus salience	High salience of the cue results in faster acquisition of responding; high salience of the outcome results in a higher asymptote of responding.
Similarity and contiguity	Similarity between the cue and outcome facilitates learning. Spatial and temporal contiguity (direct or mediated) of the cue and outcome also facilitates learning. Fast development of responding results from massed trials, but long-term retention results from distributed (i.e., spaced) trials.
Predispositions	Animals are predisposed to associate certain cues to certain outcomes. Selection of a cue and outcome that have (or had) biologically important relationships in the subject's current (or ancestral) ecological niche facilitates learning.
Contingency	Large numbers of trials that confirm the cue-outcome relationship (i.e., trials in which the two events occur and trials in which the two events do not occur) relative to the number of trials that disconfirm this relationship (i.e., trials in which the cue or outcome occur alone) facilitate learning.
Interference	Learning of a target cue-outcome relationship benefits from situations in which there are few alternative cues paired with the outcome and few alternative outcomes paired with the target cue.
Generalization	Responding benefits from high similarity between the training and testing cues.
Motivation	Even though motivation is not necessary for learning to occur, it is necessary for the expression of learned associations. The biological significance of an outcome depends on both the physical properties of the outcome and the state of the subject.

We conclude that theory has shifted the focus from some of the empirical conditions that favor (or impair) the development of learning. This is not to deny that theories of learning at the psychological level have important beneficial functions. They can: (a) predict behavior, (b) be used to control behavior, (c) organize empirical phenomena, and (d) have heuristic value in inspiring illuminating experiments that reveal previously unrecognized empirical relationships (Platt, 1964; Popper, 1959). However, in contrast to the prevailing arguments concerning appropriateness of various models, there is a rather clear set of principles (laws) that describe the conditions favoring acquired behavior, even if we do not have a model at this time which accounts for all of these principles. Importantly, optimal conditions for learning clearly vary as a function of the goals of the task at hand (e.g., rapidity of acquisition vs. resistance interference). Anyone interested in learning theory must keep these principles in mind; and researchers who are not interested in psychological theories of learning, but rather are concerned with the physiology

of learning, or the application of learning to clinical or educational problems, would be well advised to attend to these principles, rather than exclusively to the various contemporary models that have been proposed to account for these basic phenomena.

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