Context, Time, and Memory Retrieval in the Interference Paradigms of Pavlovian Learning

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In this article I review research and theory on the "interference paradigms" in Pavlovian learning. In these situations (e.g., extinction, counterconditioning, and latent inhibition), a conditioned stimulus (CS) is associated with different unconditioned stimuli (USs) or outcomes in different phases of the experiment; retroactive interference, proactive interference, or both are often observed. In all of the paradigms, contextual stimuli influence performance, and when information is available, so does the passage of time. Memories of both phases are retained, and performance may depend on which is retrieved. Despite the similarity of the paradigms, conditioning theories tend to explain them with separate mechanisms. They also do not provide an adequate account of the context's role, fail to predict the effects of time, and overemphasize the role of learning or storage deficits. By accepting 4 propositions about animal memory (i.e., contextual stimuli guide retrieval, time is a context, different memories are differentially dependent on context, and interference occurs at performance output), a memory retrieval framework can provide an integrated account of context, time, and performance in the various paradigms.

Research on simple associative learning has often focused on situations in which a subject learns information at one point in time that can conflict with information learned at some other point. Table 1 summarizes several examples of "interference paradigms" (e.g., Bouton, 1991) that have been studied in animal learning. The common feature of the paradigms is that the significance of a conditioned stimulus (CS), or its association with some other event or outcome (typically an unconditioned stimulus, or US), changes between phases of the experiment. The usual result, of course, is that learning from one phase interferes with performance appropriate to the other phase. The interference can be *retroactive*, as in extinction, when Phase 2 learning interferes with performance appropriate to Phase 1. Or it can be *proactive*, as in latent inhibition, when Phase 1 learning interferes with performance appropriate to Phase 2. The proactive paradigms are often described as negative transfer paradigms, which implies a difficulty with the actual acquisition of information in Phase 2. However, there is a possibility that the interference observed in Phase 2 could result from deficits in either acquisition or performance, and I use the

term *proactive interference* (PI) here as a more general term describing any negative influence of Phase 1 on Phase 2. Table 1 lists several examples of retroactive interference (RI) and PI, along with other paradigms that contain elements of both.

This article is concerned with how one should account for performance in the interference paradigms. It is worth noting that an analysis of the paradigms is relevant outside the interests of animal learning theory. In clinical psychology, cognitive–behavioral treatments designed to eliminate unwanted thoughts, emotions, or behaviors all take advantage of retroactive interference: New learning is designed to replace the old. Many of these treatments have been linked specifically to either extinction (e.g., Marks, 1978) or to counterconditioning (e.g., Wolpe, 1958), and basic research on these problems may have novel clinical implications (e.g., Bouton & Swartzentruber, 1991). As another example, researchers interested in the neurobiology of learning and memory have made important advances in understanding the mechanisms of acquisition in simple conditioning (e.g., Fanselow & Kim, 1992; Hawkins, Abrams, Carew, & Kandel, 1983; Thompson, 1986). Eventually, this work will need to address the mechanisms of response reduction embodied in the interference paradigms (e.g., Falls, Miserendino, & Davis, 1992). As a third example, researchers in human learning and memory have had occasion to return to the classic verbal interference paradigms (e.g., J. R. Anderson, 1983; Humphreys, Bain, & Pike, 1989; Mensink & Raaijmakers, 1988). Verbal interference has historical ties to animal conditioning phenomena (e.g., Underwood, 1948), and the animal paradigms may continue to provide an important complement because they involve motivationally significant material (cf. Hendersen, 1985). Conditioning theories are also related to some neural network, or "connectionist," models of human memory and categorization (e.g., Gluck & Bower, 1988; Shanks, 1991), in which sequential learning and interference have recently become an issue (e.g., McCloskey & Cohen, 1989).

Despite the formal similarity of the animal paradigms, learn-

Table 1
Interference Paradigms in Simple Associative Learning

Paradigm	Phase 1	Phase 2	Phase 3[a]	Type of interference
Extinction	CS+	CS−		Retroactive
Discrimination reversal learning	X+, Y−	X−, Y+		
Counterconditioning				
Aversive–appetitive transfer	CS–shock	CS–food		Retroactive and
Appetitive–aversive transfer	CS–food	CS–shock		proactive
Verbal interference	List 1	List 2		
Latent inhibition	CS−	CS+		
Hall & Pearce (1979) negative transfer	CS–shock	CS–SHOCK!		Proactive
Learned irrelevance	CS/US[b]	CS–US		
Inhibition–excitation transfer	CS, US[c]	CS–US		
Reacquisition after extinction	CS+	CS−	CS+	

Note. CS = conditioned stimulus; US = unconditioned stimulus; + = paired with US; − = presented without a US; SHOCK! = stronger shock.
[a] For reacquisition after extinction only.   [b] Uncorrelated.   [c] Negatively correlated.

ing theorists have traditionally assumed that the different examples of interference are to be explained by different mechanisms. For example, the PI observed in latent inhibition (see Table 1) is usually explained by assuming that presentation of the CS alone during Phase 1 reduces the attention to the CS (Lubow, Weiner, & Schnur, 1981; Mackintosh, 1975) or the extent to which it is otherwise processed in active memory during Phase 2 (Pearce & Hall, 1980; Wagner, 1978, 1981; Wagner & Brandon, 1989). Although this sort of mechanism has been applied to other examples of PI listed in Table 1, it has almost never been invoked to explain the PI that is also evident in discrimination reversal learning, counterconditioning, or verbal learning. It also has almost never been used to explain instances of RI such as extinction. In general, animal learning researchers have started with the assumption that RI and PI demand separate explanations.

A second assumption about interference in animal conditioning is that the interfering information interferes with what is learned during, or stored from, the target phase. Most accounts of the PI paradigms assume that Phase 1 somehow reduces the CS's ability to become associated with the US in Phase 2. For example, the main consequence of the reduced CS processing that is used to explain latent inhibition is a reduction in what is learned or stored during Phase 2 (Lubow et al., 1981; Mackintosh, 1975; Pearce & Hall, 1980; Wagner, 1978, 1981). In RI, Phase 2 learning is often assumed to replace or destroy what was encoded during Phase 1. For example, it is not uncommon to assume that extinction causes a loss in the CS–US association learned in Phase 1 (e.g., Rescorla & Wagner, 1972; see also Estes, 1955); this assumption is also made in many connectionist models of learning and memory (e.g., see McCloskey & Cohen, 1989). Thus, regardless of whether interference is proactive or retroactive, the common assumption is that interference occurs at the level of what is learned during, or stored from, the target phase.

In this article I reexamine these assumptions. I begin by examining the literature on each of the basic paradigms. The

review indicates that interference in each paradigm is controlled at least partly by contextual stimuli, stimuli that are in the background whenever learning and remembering occur. In addition, when information is available, it is also strongly influenced by the passage of time. Each example of interference may result from a common mechanism that does not necessarily involve interference at the level of learning or memory storage. Regardless of whether interference is retroactive or proactive, it may occur because the context retrieves conflicting information (see Bouton, 1991; Miller, Kasprow, & Schachtman, 1986; Spear, 1978, 1981). In a subsequent section of this article, I illustrate how the findings can be integrated with relatively simple assumptions about context, time, and memory retrieval. The approach has some similarities to theories of human verbal interference (e.g., Mensink & Raaijmakers, 1988), although it differs most importantly in proposing that retrieval of different types of memories depends differentially on context and time. By accepting certain propositions about animal memory retrieval, it is possible to provide an integrating account of context, time, and performance in the Pavlovian interference paradigms.

Interference in Simple Associative Learning

Extinction

Extinction is the most intensively studied example of RI in animal conditioning. Even though it has often been convenient to assume that extinction involves the destruction of the original CS–US association (e.g., Rescorla & Wagner, 1972), it is clear that that association can remain at least partly intact even after fairly extensive extinction training. For example, Pavlov (1927) first reported spontaneous recovery: If time is allowed to elapse following extinction, the extinguished response recovers (see also Brooks & Bouton, 1993; Rescorla & Cunningham, 1978; Robbins, 1990; D. R. Thomas & Sherman, 1986, for recent examples). Spontaneous recovery clearly suggests that at least

some of the original learning persists and may be only temporarily suppressed in performance.

Spontaneous recovery has been largely ignored by recent formal models of conditioning (e.g., Mackintosh, 1975; Pearce, 1987; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Wagner, 1978, 1981; Wagner & Brandon, 1989). More than 40 years ago, Skinner (1950) attributed it to handling cues or cues present during early parts of the extinction session: Such stimuli should undergo little direct extinction and therefore cause recovery when reintroduced at the start of a test. However, recovery still occurs when the subject is not handled at all prior to testing (D. R. Thomas & Sherman, 1986); it also occurs in the middle of test sessions, relatively remote from early session cues (Rescorla & Cunningham, 1978; Robbins, 1990; D. R. Thomas & Sherman, 1986). These findings suggest that at least some of the recovery may be controlled by the passage of time itself. Time may dissipate inhibition that develops in extinction (Hull, 1943; Konorski, 1948, 1967; Pavlov, 1927), improve attention to the CS (Robbins, 1990), or increase the probability of sampling stimulus elements that were not extinguished during extinction training (Estes, 1955). Alternatively, the passage of time could remove the subject from a temporal extinction context controlling extinction performance (Bouton, 1988, 1991; Bouton & Swartzentruber, 1991). None of these possibilities has been built into a formal analysis of conditioning since the 1950s (e.g., Estes, 1955).

Bouton (1991) has recently reviewed other phenomena suggesting that the original association is not "unlearned" in extinction. Just as the effects of extinction can be undone by the passage of time, so they can be undone by various manipulations of the physical context. For example, consider the phenomenon known as "reinstatement," in which an extinguished response is partially restored to the CS if the subject is exposed to the US alone following extinction (e.g., Rescorla & Heth, 1975). The effect results from the US exposures conditioning contextual stimuli in the background; contextual conditioning then triggers extinguished responding to the CS (Bouton & Bolles, 1979b; Bouton & King, 1983; Bouton & Peck, 1989; see Bouton, 1988, 1991, for reviews). Similar US exposures in an irrelevant context have little or no reinstating effect (Bouton, 1984; Bouton & Bolles, 1979b; Bouton & King, 1983; Bouton & Peck, 1989; see also Baker, Steinwald, & Bouton, 1991); extinction exposure to the context between US delivery and testing can reduce reinstatement (Bouton & Bolles, 1979b; see also Baker et al., 1991); and the strength of reinstated responding to the CS can be predicted from independent measurements of contextual conditioning (Bouton, 1984; Bouton & King, 1983). These findings were not anticipated by the view that US presentation after extinction restrengthens a memory of the US that was depressed by extinction (Rescorla & Heth, 1975). Reinstatement depends on contextual conditioning.

Related research on the effects of contextual conditioning helps explain how it reinstates responding to an extinguished CS. The main result is that under comparable conditions, contextual conditioning has no discernible effect on performance to a CS that is not under the influence of extinction (Bouton, 1984; Bouton & King, 1986; Bouton, Rosengard, Achenbach, Peck, & Brooks, 1993; see also Ayres & Benedict, 1973; Jenkins & Lambos, 1983; Randich & Ross, 1984; Rescorla, 1974; Sher-

man, 1978). Extinguished CSs are especially sensitive to the performance-enhancing effect of contextual conditioning: Even when extinguished and nonextinguished CSs are arranged to evoke comparable responding prior to a test, performance to the extinguished CS is enhanced by contextual conditioning, whereas performance to the nonextinguished CS is not (Bouton, 1984, Experiment 5). This pattern suggests that contextual conditioning does not merely summate with or energize (e.g., Wagner & Brandon, 1989) responding to the CS in the reinstatement paradigm. It also questions the possibility that the animal merely generalizes from the newly conditioned context to the CS–context compound (cf. Pearce, 1987). Instead, reinstatement may occur because contextual conditioning was part of the background associated with conditioning; during testing, the extinguished CS is in effect returned to a feature of the conditioning "context" (Bouton et al., 1993).

According to this analysis, reinstatement may be a special case of another effect of context known as the "renewal effect." In the basic demonstration of renewal, a CS is paired with a US in one context (Context A) and then presented alone so as to extinguish responding in another (Context B). Responding to the CS is "renewed" when the CS is removed from Context B and tested in Context A (e.g., Bouton & Bolles, 1979a; Bouton & King, 1983; Bouton & Swartzentruber, 1989). Renewal can occur after as many as 84 extinction trials (Bouton & Swartzentruber, 1989); it can also occur if testing occurs in a third, neutral context (Bouton & Bolles, 1979a; Bouton & Swartzentruber, 1986, 1989, Experiment 3). The effect has been demonstrated in aversive conditioning (e.g., Bouton & Bolles, 1979a; Bouton & King, 1983), appetitive conditioning (Bouton & Peck, 1989), instrumental conditioning (Welker & McAuley, 1978; see also Ahlers & Richardson, 1985), and taste aversion learning (e.g., Archer, Sjoden, Nilsson, & Carter, 1979). It may also be produced by several types of contexts. Fear extinguished in the presence of a drug "context" provided by alcohol (Cunningham, 1979) or benzodiazepine tranquilizers (Bouton, Kenney, & Rosengard, 1990) may be renewed when the rat is returned to and tested in the sober state. Similarly, extinguished avoidance behavior may be renewed when the rat is returned to the hormonal conditioning context by administering adrenocorticotrophic hormone prior to testing (Ahlers & Richardson, 1985; Richardson, Riccio, & Devine, 1984). These observations suggest that the renewal effect is fairly general. After extinction in a variety of preparations, performance depends importantly on the context.

Considerable research has investigated how contexts control performance in the renewal paradigm (see Bouton, 1991, for a review). The issues are worth discussing here because they also emerge in other interference paradigms. On the surface, the renewal effect (along with other context discrimination effects; see Bouton, 1991) is consistent with familiar principles of compound conditioning (e.g., Rescorla & Wagner, 1972), which assume that the context enters into a direct association with the US. Context A may acquire an excitatory association with the US during conditioning, and Context B may acquire an inhibitory association when it is nonreinforced in combination with the CS during extinction. These associations would be expected to combine (summate) with the CS–US association to produce performance to the CS–context compound. However, this anal-

ysis has not stood up to direct tests. First, the idea that context and CS merely summate ran into trouble in research described earlier in which contextual conditioning on its own was shown to have little impact on performance to a CS (e.g., Bouton, 1984; Bouton & King, 1986; Bouton et al., 1993). Furthermore, in typical renewal procedures, Context A does not arouse responding on its own, even when assessed with multiple techniques (Bouton & King, 1983), and extensive extinction exposure to Context A alone before testing does not abolish renewal (Bouton & King, 1983; Bouton & Swartzentruber, 1986, 1989) or detectably reduce it (Bouton & Peck, 1989). When context–US associations are made especially strong by alternating sessions containing CS–US pairings in Context A and CSs alone in Context B, the two contexts fail to control behavior on their own, fail to summate with other CSs, and fail to affect learning to other CSs in ways that traditional excitors and inhibitors are expected to (Bouton & Swartzentruber, 1986). Demonstrable context–US associations thus do not appear to be *necessary* for the context to affect performance to a CS. Together with the evidence suggesting that context–US associations are not *sufficient* to affect CS performance (Bouton, 1984; Bouton & King, 1986; Bouton et al., 1993), the results suggest that performance to a CS is not a function of summation between context–US and CS–US associations.

Another account of renewal could emphasize configural conditioning. That is, each combination of CS and context could constitute a distinct stimulus that itself acquires excitation or inhibition (see Kehoe & Gormezano, 1980; Pearce, 1987; Rescorla, 1973). This approach is generally more successful than the approach assuming separate context–US and CS–US associations. However, there may be problems here as well. If each CS–context combination produces a unique configuration, one would expect some loss of responding when the CS is switched to Context B following conditioning in Context A. In a number of experiments, no such response loss has been observed (Bouton & King, 1983; Bouton & Peck, 1989; Bouton & Swartzentruber, 1986, 1989; Hall & Honey, 1989; Kaye, Preston, Szabo, Druiff, & Mackintosh, 1987); in other cases in which a response loss has been observed, a role for configural cues has been similarly eliminated on other grounds (e.g., Hall & Honey, 1989). Also counter to an analysis emphasizing unique configural stimuli, the context's control of responding to one CS can transfer to a separate CS under some conditions (Swartzentruber & Bouton, 1988). The renewal effect may not depend on simple configural conditioning.

An alternative is that instead of simply being associated with a US, the context may signal or retrieve the CS–US association (Bouton & Bolles, 1985; see also Estes, 1973; Spear, e.g., 1973). Thus, the context of conditioning may signal the CS–US association, whereas the context of extinction may signal some representation of extinction (e.g., CS–no US). The extinguished CS has properties resembling an ambiguous word (Bouton, 1984, 1988; Bouton & Bolles, 1985): It has two available meanings that are selected or retrieved by its current context. The context appears to have properties similar to Pavlovian occasion setters (e.g., Holland, 1983, 1985, 1992; Ross & Holland, 1981) and facilitators (e.g., Rescorla, 1985); the parallel has been discussed in detail elsewhere (Bouton, 1991; Bouton & Swartzentruber,

1986; Swartzentruber, 1991). Both types of stimuli may signal or enable the association between the CS and the US.

The results reviewed here suggest that contextual stimuli and time both have important effects on performance in extinction. To date, the evidence weighs against the assumption that binary associations between the context and US are necessary and sufficient to affect CS performance. It is therefore reasonable to suppose that contexts control responding to CSs embedded in them through a mechanism other than summation. Most of the data are consistent with the view that contexts work by retrieving, signaling, or setting the occasion for CS–US associations. Bouton (1991) suggested that extinction is a retrieval problem in which representations of both phases are stored, ready to be retrieved by context. What determines performance, then, is the extent to which each is retrieved.

Discrimination Reversal Learning

These observations are consistent with other paradigms involving retroactive interference. Consider discrimination reversal learning, which contains both RI and PI. In this paradigm, discriminative training with two stimuli, $X+$ and $Y-$, is reversed ($X-$ and $Y+$) in a second phase. Initial $X+/Y-$ training interferes proactively with performance according to $X-/Y+$; in addition, $X-/Y+$ training during Phase 2 interferes retroactively with performance according to $X+/Y-$.

The paradigm has been studied extensively in avoidance learning by Spear and Gordon and their colleagues. In their method, rats are initially trained to avoid passively the black compartment of a black–white box ($B+/W-$); in Phase 2, they are trained to avoid actively white ($W+/B-$). During testing, the rat is placed in the white compartment and latency to leave is measured. Long latencies suggest retrieval of the passive avoidance ($B+/W-$) memory, whereas short latencies suggest active avoidance ($B-/W+$). When the first and second phases are conducted in different contexts, a return to the Phase 1 context after reversal training renews passive avoidance (Phase 1) performance (Spear, 1971; Spear et al., 1980; see also Dekeyne & Deweer, 1990). Responding during the test appears to be bimodal; the rats tend to give either passive or active avoidance responses (e.g., Spear, 1971). Renewal of passive performance has been demonstrated with both room and drug (pentobarbital) contextual stimuli (Spear et al., 1980). This result parallels the renewal effect observed after extinction.

Thomas and his associates have reported complementary results in appetitive operant conditioning in pigeons (e.g., D. R. Thomas, McKelvie, & Mah, 1985; D. R. Thomas, McKelvie, Ranney, & Moye, 1981; D. R. Thomas, Moye, & Kimose, 1984). Here, the study usually involves reinforcement of one of two colored keylights, a reversal, and then generalization tests around X and Y in the "context" (typically combinations of houselight and auditory stimuli) associated with either Phase 1 or Phase 2. With this method, the pigeon generalizes around X and Y in a manner that is appropriate to the context of testing. That is, a return to the Phase 1 context renews Phase 1 performance, with a peak of responding around X rather than Y (D. R. Thomas et al., 1981, 1984, 1985).

Recent research on aversive conditioning in rats provides additional details (Bouton & Brooks, 1993). In this work, the ef-

fects of context were tested separately on X and Y; previous studies had tested X and Y simultaneously (e.g., Spear et al., 1980) or with relative rate measures (e.g., D. R. Thomas et al., 1981) that made it difficult to be precise about the separate effects on X and Y. A return to the Phase 1 context after reversal in a different context renewed performance to X and reduced performance to Y (see also Swartzentruber, 1993). Tests in a third context also confirmed that the contexts of Phases 1 and 2 both controlled performance. However, responding to X and Y did not always change as a unit (see following paragraphs), suggesting that they had not been coded together in a coherent representation of Phase 1 and Phase 2. Instead, X and Y behaved as if they were run in separate experiments on extinction (X) and latent inhibition (Y).

Renewal in discrimination reversal learning is informative for several reasons. First, it again suggests that RI is not caused by a destruction of knowledge acquired in Phase 1. Second, note that a return to the Phase 1 context not only renews Phase 1 performance but that it also resuppresses aspects of Phase 2 performance (see also G. J. Smith & Spear, 1979). This renewal of PI suggests that proactive effects, like retroactive ones, may result from a retrieval or performance mechanism. Indeed, the interference observed during actual Phase 2 reversal learning is attenuated by a context switch in the pigeon preparation (e.g., D. R. Thomas et al., 1981). In conditioned suppression, such negative transfer is also attenuated by a context switch (Bouton & Brooks, 1993), although there the attenuation appears to be specific to the stimulus that was nonreinforced prior to reinforcement (Y). Like RI, PI may result from contextual cuing of Phase 1 information.

The effects of context in discrimination reversal learning are interesting for at least one other reason: The renewal effect implies that the animal has learned a conditional discrimination (it responds to AX and BY but not to AY and BX) that cannot be solved on the basis of associations to the individual elements alone (A, B, X, and Y). For example, because renewal on return to the Phase 1 context (A) may simultaneously involve an increase in responding to X and a decrease in responding to Y (Bouton & Brooks, 1993; Swartzentruber, 1993), a simple excitatory or inhibitory association to the context cannot account for the pattern, as it could, at least in principle, for renewal after extinction. Conditional discriminations are traditionally assumed to be controlled by configural cues. Thus, during Phase 1 training in Context A, the animal may learn excitation to the unique configuration AX and an inhibitory association to the configuration AY (see Pearce, 1987, and Wilson & Pearce, 1989, for a variation on this analysis). However, the renewal effect appears strongest in the pigeon preparation with stimulus combinations that seem the least likely to yield distinct perceptual cues. For example, simultaneous houselights and tones (D. R. Thomas et al., 1981, 1984, 1985) or keylights arranged in a serial relation with the target keylight (D. R. Thomas, Curran, & Russell, 1988) produce renewal, but *simultaneous* projection of two keylight stimuli, in a manner that could be expected to produce configural cues at a perceptual level, do not (D. R. Thomas et al., 1985). The difference between serial and simultaneous keylights is reminiscent of the occasion-setting literature, in which serial feature–target combinations yield conditional control, whereas simultaneous feature–target compounds do not (e.g.,

Holland, 1985). The available data strain the view that the renewal effect is controlled by unique perceptual cues, although it is clear that the animal must code specific information about particular combinations of the CS and context in this paradigm.

As in extinction, performance in discrimination reversal learning can also be affected by the passage of time following Phase 2. In the passive–active avoidance procedure, Phase 1 performance has been observed to recover over time, as suggested by an increase in latency to leave the start box (Gordon, Frankl, & Hamberg, 1979; Gordon & Spear, 1973; Spear et al., 1980). Similar recovery of Phase 1 performance has been observed in T-maze reversal (Chiszar & Spear, 1969) and in other reversed appetitive discrimination tasks (e.g., see Gleitman, 1971; Spear, 1971). Time also has effects in the pigeon operant preparation, although its effects may be more complex (Burr & Thomas, 1972; D. R. Thomas et al., 1984). Interpretation of some data in this literature is complicated by the absence of nonreversed controls. In addition, the nearly universal use of either relative response measures or tests in which X and Y are presented simultaneously have made it difficult to know whether changes in performance over time reflect absolute changes in responding to X, Y, or both stimuli. When separate measures of responding to X and Y have been made, absolute recovery occurs to X (the conditioned-then-extinguished CS) with relatively little change occurring to Y (Bouton & Brooks, 1993; Kraemer, 1984).

The discrimination reversal literature indicates that the manipulation of time and context can have important effects on performance. Once again, current models of conditioning do not address the effects of time, and context effects require more than simple summation between associative strengths of the CSs and the contexts. Furthermore, the data consistently suggest that both RI and PI may be controlled by the retrieval of conflicting information from the interfering phase. This hypothesis has actually been the guiding principle behind most of the research in this paradigm (e.g., Spear, 1981; D. R. Thomas, 1981). One important advantage of a retrieval approach is that it can integrate the effects of context and time.

Counterconditioning

Another paradigm that mixes RI and PI is counterconditioning, or cross-motivational transfer. Here, a CS is first associated with a US from one motivational system and then subsequently associated with a US from another. In aversive-to-appetitive transfer, CS–shock pairings precede CS–food (or CS–water) pairings; in appetitive-to-aversive transfer, CS–food (or CS–water) pairings precede CS–shock pairings. Both paradigms clearly involve RI; Phase 2 training abolishes Phase 1 performance. Furthermore, initial aversive conditioning proactively interferes with appetitive performance in the aversive–appetitive paradigm (e.g., Bouton & Peck, 1992; Bromage & Scavio, 1978; Kaye et al., 1987; Krank, 1985; Peck & Bouton, 1990; Scavio, 1974). The interference appears to be caused by a central process, rather than by competition between incompatible peripheral responses, because it occurs even when the aversive and appetitive conditioned responses (CRs) are statistically independent of one another (Scavio, 1974; see also Bromage &

Scavio, 1978; Krank, 1985). Negative transfer occurs less consistently in appetitive–aversive transfer, wherein initial appetitive conditioning has retarded (Bouton & Peck, 1992; Dickinson, 1976; Konorski & Szwejkowska, 1956), facilitated (DeVito & Fowler, 1982; Scavio & Gormezano, 1980), and had no effect on (Jackson, 1974; Peck & Bouton, 1990) aversive conditioning in Phase 2.

The view guiding most research in this paradigm is that excitatory aversive and appetitive motivational systems inhibit one another reciprocally (Dickinson & Dearing, 1979; Konorski, 1967; Rescorla & Solomon, 1967). In associative terms, excitatory associations in one system are assumed to be equivalent to inhibitory associations in the other. Within the terms of the Rescorla–Wagner model, they have opposite algebraic signs (e.g., see Krank, 1985; also see Daly & Daly, 1982, 1987, for an extension of this analysis). In this view, a negatively valued aversive excitor, for example, would be slow to acquire the positive value of an appetitive CS. Negative transfer thus occurs at the level of learning. Transformation of the CS into an appetitive excitor would similarly destroy its negative Phase 1 association; RI once again results from a storage deficit. Identical assumptions have been built into the analysis of human learning tasks in which different stimuli or features are associated with more than one outcome or category (e.g., Gluck & Bower, 1988).

Recent research suggests the value of viewing counterconditioning from a retrieval framework. Peck and Bouton (1990) found that when the two phases were conducted in different contexts, a return to the Phase 1 context after the completion of Phase 2 renewed the Phase 1 CR (e.g., defensive freezing) and resuppressed the Phase 2 CR (e.g., appetitive head jerking). As in extinction and discrimination reversal learning, Phase 1 knowledge was not abolished during Phase 2. In addition, the fact that a return to the Phase 1 context resuppressed Phase 2 performance (i.e., renewed PI) is consistent with the view that interference can occur at the level of retrieval rather than learning. A context switch between Phases 1 and 2 also reduced PI (but see Kaye et al., 1987). A renewal of Phase 1 and resuppression of Phase 2 was found in both aversive–appetitive and appetitive–aversive transfer (Peck & Bouton, 1990).

Peck and Bouton (1990) noted that their results were consistent with either the view that associative strength of a CS and context summate or that the contexts provide retrieval cues for the separate CS–US associations. It is also possible that configural conditioning could account for the findings. They noted, however, that the simple summation view fails in tests in the extinction paradigm: As reviewed earlier, contexts and CSs do not appear to summate especially well in performance. It may also be noted that a simple reduction in the associability of the CS that could result during Phase 1 conditioning (Pearce & Hall, 1980; Wagner, 1978, 1981) cannot account for the renewal of interference produced with a return to the Phase 1 context. Thus, either the retrieval view, in which the context retrieves CS–shock and CS–food associations, or a configural conditioning view, provides the most accurate account of the effects of context.

Bouton and Peck (1992) more recently found that performance in this paradigm is also sensitive to the effects of the passage of time after Phase 2. In both aversive–appetitive and appetitive–aversive transfer, a 28-day retention interval after the conclusion of Phase 2 caused a recovery of the Phase 1 CR and a resuppression of the Phase 2 CR. Notice that an emphasis on configural conditioning does not anticipate the effects of time. The results were also not anticipated by a recent explanation of spontaneous recovery in extinction proposing that an attentional response to the CS recovers over time (Robbins, 1990). Instead, memories of both phases appear to be retained after Phase 2; once again, both RI and PI effects may come about through performance interference mechanisms. Performance in cross-motivational transfer, as in extinction and discrimination reversal learning, is affected by context (Peck & Bouton, 1990) and time (Bouton & Peck, 1992). The only account equipped to deal with both types of effect is a memory-retrieval view: Performance in counterconditioning may be determined by which of the available memories is retrieved.

Verbal Interference

The terms *proactive interference* and *retroactive interference*, of course, originated in the large literature on verbal interference in humans (e.g., Postman & Underwood, 1973). When humans memorize two consecutive lists, instructions to recall List 1 can reveal RI from List 2, whereas instructions to recall List 2 reveal PI. Like discrimination reversal and aversive–appetitive transfer, the list-learning experiment involves both retroactive and proactive influences.

Although verbal interference is not a central concern of this article, it is worth noting that the factors that influence interference in animal conditioning also operate here. For example, background contextual stimuli are important in controlling verbal interference (e.g., Bilodeau & Schlosberg, 1951; Dallett & Wilcox, 1968; Greenspoon & Ranyard, 1957; see S. M. Smith, 1988, for a recent review). In Greenspoon and Ranyard's (1957) study of RI, undergraduates learned two lists; when the second list was learned in a room different from that of the first, a return to the Phase 1 room renewed recall and facilitated relearning of the original list. In related experiments, Tulving and Psotka (1971) renewed recall of List 1 by providing retrieval cues (category labels) for the words of List 1. In their studies of PI, Dallett and Wilcox (1968) found that lists of words were recalled better a day later if they had been learned in a context that differed from those in which previous interfering lists had been learned. There is a clear similarity between these context effects and those in the animal paradigms.

Time is also notoriously important in determining PI and RI after Phase 2 learning has occurred. According to the results of several studies, PI increases but RI decreases over time (e.g., Postman, Stark, & Fraser, 1968; Underwood, 1948). It is worth noting, however, that a general reduction in List 2 recall is often more evident than is an absolute recovery of List 1 (see Postman et al., 1968). Relatively recent accounts of verbal interference have emphasized retrieval processes consistent with those under consideration here (e.g., Mensink & Raaijmakers, 1988; Tulving & Psotka, 1971).

Latent Inhibition

Nonreinforced preexposure to a CS interferes with conditioning that occurs when the CS is subsequently paired with a

US. "Latent inhibition," as this effect is called, was the focus of an intensive research effort during the 1970s and 1980s. Unlike the paradigms addressed thus far, it is seen exclusively as a PI problem; the focus is Phase 1's effect on Phase 2 rather than the reverse. Consistent with the separation, theories of latent inhibition have progressed more or less independently of the preceding paradigms. The dominant idea is that during Phase 1, the animal learns to process the CS less; this has been described as a loss of attention (e.g., Mackintosh, 1975), a loss of associability (Pearce & Hall, 1980), the learning of inattention (e.g., Lubow et al., 1981), and habituation of rehearsal or level of activity (Wagner, 1978, 1981; see also McLaren, Kaye, & Mackintosh, 1989). Although the various models propose different rules governing this process, they universally assume that the reduced CS processing interferes with subsequent learning during Phase 2.

Perhaps the most important finding to emerge on latent inhibition in the 1980s is that it depends importantly on context. In several conditioning preparations, the effect is strongly attenuated if the context is changed between Phases 1 and 2 (e.g., Channell & Hall, 1983; Gordon & Weaver, 1989; Hall & Channell, 1985; Hall & Minor, 1984; Kaye et al., 1987; Lovibond, Preston, & Mackintosh, 1984; Swartzentruber & Bouton, 1986; but see Baker & Mercier, 1982). This effect of context was not anticipated by some models (Lubow et al., 1981; Mackintosh, 1975; Pearce & Hall, 1980) but was specifically predicted by the models of Wagner (1978, 1981). These models assume that the subject learns to associate the CS with the context during Phase 1; the context therefore signals the CS, thereby habituating its surprisingness and the degree to which it is active (Wagner, 1981) or rehearsed (Wagner, 1978) when it is paired with the US in Phase 2. Context–CS association therefore reduce the degree to which the CS can enter into an association with the US. A context switch between phases dishabituates the surprisingness of the CS. McLaren et al. (1989) have recently suggested a similar mechanism.

In spite of its ability to predict a role for context, the Wagner (1978, 1981) habituation mechanism has not fared well. For example, compounding the CS with another CS in Phase 1, which could overshadow the learning of context–CS associations, does not consistently abolish latent inhibition (Mercier & Baker, 1985), nor does nonreinforced exposure to the context prior to Phase 2 consistently affect the phenomenon (Baker & Mercier, 1982; Hall & Minor, 1984). Perhaps most important, however, is the fact that context-specific habituation has not been confirmed in a number of different habituation preparations (Baker & Mercier, 1982; Bouton & Brooks, 1993; Churchill, Remington, & Siddle, 1987; Hall & Channell, 1985; Leaton, 1974; Marlin & Miller, 1981). It is possible that the rate at which a stimulus develops conditioned responding is a more sensitive test of context-specific habituation than is a mere examination of unconditional responding (but see Hall & Schachtman, 1987). Nevertheless, the failure to confirm such an effect with stimuli that function as CSs is a significant problem for the model.

The context specificity of latent inhibition is also consistent with a retrieval view (e.g., Bouton, 1991; Spear, 1981; see also Baker & Mercier, 1989; Hall, 1991). It is possible that the animal may treat the CS as familiar in a different context (and thus

continue to show habituation) but fail to remember what it means (and thus show a loss in latent inhibition). Contextual retrieval of a representation of the CS without the US could ordinarily interfere with CS–US performance; a context switch between phases could reduce retrieval of a memory of the CS alone and thus the interference effect. Consistent with this analysis, Gordon and Weaver (1989) found that latent inhibition that was lost with a context switch was restored if the rat received a retrieval cue (a noise featured during preexposure) a few minutes before conditioning. In effect, latent inhibition transferred between contexts if the animal received a treatment that alleviated forgetting. Similar effects have been produced in discrimination reversal learning (e.g., Gordon, Mowrer, McGinnis, & McDermott, 1985).

The retrieval view emphasizes an interference effect that occurs at the level of performance rather than learning. There is in fact surprisingly little evidence that confirms the conventional assumption that CS preexposure interferes with learning. Also, several lines of evidence suggest that latent inhibition may result from performance interference. Kasprow, Catterson, Schachtman, and Miller (1984) found that a "reminder treatment" (two US exposures in a different chamber 3 days before the final test) caused a latent-inhibition group to increase its performance substantially. Controls that had received conditioning without latent-inhibition training were not significantly affected by the same treatment; thus, the treatment appeared to work by releasing a learned CS–US association from interference. This finding should be viewed with caution, however, because there was a trend toward a difference between the control groups that could have been underestimated because of their higher position on a logarithmic scale.

Other results suggest that an analogue of the renewal effect can occur in latent inhibition: If preexposure and conditioning occur in different contexts, returning the rat to the preexposure context after conditioning can renew interference with conditioned performance (e.g., Bouton & Bolles, 1979a; Bouton & Brooks, 1993; Bouton & Swartzentruber, 1989; Dexter & Merrill, 1969; Wright, Skala, & Peuser, 1986; see also D. C. Anderson, Merrill, Dexter, & Alleman, 1968; D. C. Anderson, O'Farrell, Formica, & Caponigri, 1969). This effect's recent demonstration under relatively well-controlled conditions (Bouton & Swartzentruber, 1989; see also Bouton & Brooks, 1993, and Lovibond et al., 1984, as reanalyzed by Bouton, 1991, p. 44) puts the results on reasonably firm ground. It suggests again that CS preexposure can interfere with conditioning through a performance interference mechanism and that this mechanism can be controlled by context. In addition, traditional context–US associations cannot readily account for the effect. Although the context of preexposure "inhibits" conditioned responding in the final test, that context has never been associated with the offset of a US or nonreinforcement of an excitatory CS, conditions that are universally required for the development of inhibition (e.g., Pearce, 1987; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Wagner, 1978, 1981). Thus, the renewal of latent inhibition lies outside of the scope of models that can in principle account for the renewal effect in, say, the extinction paradigm.

It may be possible, however, to account for the preexposure cuing effect in terms of context–CS associations. Wagner's (e.g.,

1981) *sometimes-opponent process* or "SOP" model would suggest that initial context–CS associations would allow the context to put elements of the CS node into a secondary level of activation; when the CS itself is presented, there are fewer elements available to put into the primary active state. If the CR depends on the CS elements being in the primary state, then this mechanism would reduce the CR in the preexposure context. However, this is the mechanism that also predicts context-specific habituation. If one accepts that there is little evidence to support the existence of that phenomenon, then there are no grounds for invoking the mechanism again here. It is also relevant to note the parallel with other paradigms, such as counterconditioning (Peck & Bouton, 1990), wherein a return to the Phase 1 context causes resuppression of the Phase 2 CR but also an increase in a Phase 1 CR. Such a finding clearly suggests that a renewal of PI can occur even when CS elements are in an active state.

As in other paradigms, the passage of time may have important effects in latent inhibition. If a retention interval is inserted between the preexposure and conditioning phases, latent inhibition is substantially reduced (Hall & Minor, 1984; Kraemer & Roberts, 1984; McIntosh & Tarpy, 1977). More provocative effects of time after Phase 2 have been reported in taste aversion procedures (Kraemer, Hoffman, & Spear, 1988; Kraemer & Ossenkopp, 1986; Kraemer & Roberts, 1984; Kraemer & Spear, 1992). In one variation of the procedure (e.g., Kraemer & Roberts, 1984), rats receive preexposure to apple juice; then, on a single conditioning trial, they receive a pairing of saccharin with lithium chloride poisoning. When the saccharin aversion is tested 1 day later, preexposure to apple juice interferes with the saccharin aversion; preexposed subjects show a weaker saccharin aversion than controls receiving no preexposure. However, when testing occurs 21 days later, the interference effect is gone: The "inhibited" aversion to saccharin recovers, or becomes manifest in performance, over the retention interval. This result suggests that preexposure did not interfere with the learning of the CS–US association but temporarily interfered with its performance.

The procedure just described is not a true latent-inhibition design because preexposure and conditioning were conducted with different flavors. Kraemer and his associates used a more traditional latent-inhibition procedure and obtained similar results when chocolate milk was used as both the preexposed and conditional stimulus (Kraemer et al., 1988; Kraemer & Roberts, 1984; but see Kraemer & Ossenkopp, 1986); latent inhibition evident 1 day after conditioning was lost 21 days later. However, when saccharin was used on both types of trials, the interference effect was maintained over the same retention interval (Kraemer & Roberts, 1984). A more recent latent inhibition experiment in fear conditioning produced favorable results (Kraemer, Randall, & Carbary, 1991), although baseline differences among the groups could make alternative explanations possible. It is also worth noting that earlier studies reported exactly the opposite result: Interference with appetitive runway running can recover (rather than decline) over time when reinforced training is preceded by nonreinforced trials (Spear, Hill, & O'Sullivan, 1965; see also Spear & Spitzner, 1967). There are thus discrepancies in the literature, and a complete explanation will be complex. Nonetheless, the various effects of time all

suggest that nonreinforced preexposure may interfere with the *expression* of learned performance. Such effects are consistent with a retrieval model, but not with models that simply assume an interference with learning.

As in the other paradigms, time and context appear to have important effects in latent inhibition. Although Wagner's (1978, 1981) views have stimulated much research, they have encountered trouble in the area of context-specific habituation and cannot account for some of the more interesting effects of time. Furthermore, the results of reminder treatments (Kasprow et al., 1984), the renewal effect (e.g., Bouton & Swartzentruber, 1989), and the effects of time following Phase 2 (e.g., Kraemer et al., 1991; Kraemer & Roberts, 1984) each suggest that interference may occur at the level of retrieval or performance interference. Overall, retrieval appears to play a significant role in the latent-inhibition paradigm (see also Hall, 1991).

Hall–Pearce Negative Transfer

A latent-inhibition-like effect can be produced in the conditioned suppression preparation if the CS is paired with a weak shock in Phase 1 and then a stronger shock in Phase 2; that is, CS–weak US pairings can interfere proactively with CS–strong shock performance (e.g., Hall & Pearce, 1979). This phenomenon contradicts the idea that a CS gains associability as it is associated with a US (Mackintosh, 1975). However, it is consistent with either the Wagner (1978, 1981) models, which invoke the context–CS association mechanism described earlier for latent inhibition, the retrieval view, or the Pearce–Hall model (Pearce & Hall, 1980). The latter model assumes that a CS *loses* associability as it becomes a better predictor of trial outcomes; as a result of consistent CS–weak US pairings, the animal is unable to learn the new CS–strong US association. Especially consistent with this view is the finding that two nonreinforced trials inserted prior to strong US training can attenuate negative transfer (Hall & Pearce, 1982). The model predicted this result on the basis of its proposition that associability increases as long as the outcome of a given trial is surprising. PI is again assumed to result from a learning failure during Phase 2.

Swartzentruber and Bouton (1986) found that a context switch between phases attenuated Hall and Pearce's (1979) negative transfer, much as it attenuated latent inhibition. Furthermore, they noted (as had Bouton, 1986) that a role for context can explain a problematic result reported by Ayres, Moore, and Vigorito (1984). Ayres et al. observed negative transfer in conditioned suppression, which involved 23-min intertrial intervals, but not in rabbit eyeblink conditioning, which involved intertrial intervals of 30 s and less. In the massed-trial procedures used in the eyeblink preparation, aftereffects of the strong shocks delivered in Phase 2 could have created a new context. It is also possible that nonreinforced trials inserted between phases (Hall & Pearce, 1982) may function to mark the phases. In short, context may play an important role in this paradigm, much as it does in others. Furthermore, the Pearce–Hall model does not anticipate an effect of context without adding a configural conditioning assumption. However, no research has been undertaken to separate the views of Wagner (1978, 1981) from a retrieval interpretation of the effect of context in this paradigm.

To date, there have been no tests of the renewal effect or of the effects of time.

Learned Irrelevance

Mackintosh (1973) reported that exposure to a CS and US in an uncorrelated manner interferes with subsequent conditioning more than does exposure to the CS or the US alone. The finding has been replicated and extended (e.g., Baker & Mackintosh, 1977, 1979). In addition, as with latent inhibition and Hall–Pearce (Hall & Pearce, 1979) negative transfer, the context plays a role. A context switch between phases at least partially attenuates the effect (Kaye & Mackintosh, 1990; Matzel, Schachtman, & Miller, 1988; see also Kaye et al., 1987; Tomie, 1981; Tomie, Murphy, Fath, & Jackson, 1980). In this sense, then, learned irrelevance is consistent with the other interference paradigms. I am not aware of any research that has investigated the effects of time or other context switch effects.

A persistent question surrounding learned irrelevance, however, is whether the effect is more than the sum of the separate effects of CS and US preexposure. (Like preexposure to the CS, preexposure to the US alone can hinder subsequent conditioning; e.g., Randich & Lolordo, 1979.) Manipulations that appear to eliminate the CS and US preexposure effects only partially attenuate learned irrelevance (Matzel et al., 1988; see also Baker & Mackintosh, 1979). Although this sort of result suggests that learned irrelevance may be more than the sum of its parts, there is an almost intractable problem that two unobserved, subthreshold, effects of the constituent processes can still combine to produce the irrelevance effect that remains. Perhaps the only way out of this problem would be to find manipulations that actually *reverse* the constituent effects and show that these do not abolish learned irrelevance. This has yet to be done. Therefore, at present, it may be safest to conclude that learned irrelevance may result from some subtle combination of two separate PI processes (latent inhibition and the US preexposure effect), both of which are sensitive to context. It follows, then, that any explanation of the constituent processes will be sufficient to explain learned irrelevance. One of these processes is, of course, the retrieval view.

Inhibition–Excitation Transfer

It is well known that a conditioned inhibitor is slow to acquire excitatory responding when it is paired with the US in a second phase; the result is well entrenched as a standard test for inhibition, the so-called "retardation-of-acquisition test" (e.g., Rescorla, 1969). The traditional view assumes that inhibitory conditioning interferes with the acquisition of the new excitatory association and that excitatory training destroys the original inhibition (e.g., Rescorla & Wagner, 1972). This paradigm is commonly used as the model for explaining the counterconditioning paradigm (see earlier *Counterconditioning* section).

Recent evidence suggests, however, that conditioned inhibitors can retain considerable inhibition even after they have been converted into conditioned excitors (Jenkins, 1985; Pearce & Wilson, 1991; Rescorla, 1985). Excitatory conditioning may "mask" but does not necessarily destroy the original inhibition (Rescorla, 1985). In a recent experiment conducted in my labo-

ratory, Peck (1993) found that when inhibition and then excitation training were conducted in different contexts, a return to the inhibition context resulted in renewed inhibitory performance (and resuppressed excitatory performance) to the newly excitatory stimulus. Such results are consistent with the view that the Phase 1 and Phase 2 contexts control PI and RI in this paradigm. Once again, interference may occur at retrieval rather than during learning.

Reacquisition After Extinction

CS–US pairings can be resumed after extinction; reacquisition so induced has usually been thought to be more rapid than original conditioning. This effect is consistent with many views that allow some remnant of excitation to remain following extinction (e.g., Kehoe, 1988). The Pavlovian literature supporting this result primarily involves salivary and defensive paw reflexes in dogs (Konorski & Szwejkowska, 1950, 1952a, 1952b; Szwejkowska, 1950; see also Shurrager & Culler, 1940) and eyeblink or nictitating membrane responses in rabbits (Frey & Butler, 1977; Frey & Ross, 1968; Hoehler, Kirschenbaum, & Leonard, 1973; Napier, Macrae, & Kehoe, 1992; M. Smith & Gormezano, 1965). However, in reviewing the studies prior to 1986, Bouton (1986) noted, first, that no experiment had included a control group to establish that an extinguished CS acquired responding more rapidly than a novel stimulus paired with the US at the same point in the experiment. More important, rapid recovery of the CR usually could have come about by some process that does not require actual CS–US *pairings*. For example, in several studies CS–US pairings were begun following a 24-hr rest that would have been sufficient to allow spontaneous recovery (e.g., Hoehler et al., 1973; M. Smith & Gormezano, 1965). In addition, many experiments involved massed conditioning and reconditioning trials; in such procedures, the aftereffects of recent USs could cause recovery of the response in a manner similar to the renewal effect (e.g., Frey & Butler, 1977; Frey & Ross, 1968; Hoehler et al., 1973; Shurrager & Culler, 1940; M. Smith & Gormezano, 1965; but see Napier et al., 1992). Thus, although one may observe rapid recovery of the CR when CS–US pairings follow extinction, there is surprisingly little evidence that would distinguish the effect from either spontaneous recovery or renewal. A recent set of experiments on the rabbit nictitating membrane response may be the only exception to this rule (Napier et al., 1992).

Recent work on reacquisition in the conditioned suppression situation suggests that reacquisition can actually be slow under some conditions. Bouton (1986) found that after 8 initial conditioning trials, 16 or 24 extinction trials yielded a CS that acquired suppression at a rate that was indistinguishable from that of a novel CS. With 72 extinction trials, however, reacquisition was slower than was acquisition with a novel CS. This result was replicated by Bouton and Swartzentruber (1989), who showed that reacquisition, although slow, was not as slow as acquisition following a comparable number of CS exposures without initial conditioning. In addition, context played a role: When the context was switched after extinction, reacquisition occurred at a faster rate. Perhaps most important, when extinction and reconditioning were conducted in different contexts, a return to the extinction context produced an immediate re-

newal of extinction performance and, thus, a renewal of interference with reconditioning performance. These results suggest that slow reacquisition can occur because of performance interference.

The fact that extinction training can produce interference with subsequent reconditioning, although somewhat surprising, is actually consistent with any model that allows for decreases in attention or associability with repeated exposure to a CS (Lubow et al., 1981; Pearce & Hall, 1980; Wagner, 1978, 1981). However, the isolation of a performance interference effect controlled by context (Bouton & Swartzentruber, 1989) limits the field to a smaller set of contenders. Once again, one can ask whether renewal was caused by context–CS associations reducing the strength of the CR (Wagner, 1981), a possibility that is inconsistent with the lack of context specificity of habituation. Alternatively, perhaps inhibitory context–US associations learned during extinction mediated the renewal of extinction performance; however, summation tests of a second CS presented in the extinction context revealed no evidence that it had acquired traditional inhibitory properties. Extinction appears to produce a CS with mixed properties. In the presence of contextual cues associated with extinction, extinction performance and slow reacquisition may occur. However, in the absence of those cues, or in the presence of cues associated with conditioning, conditioning performance is observed. Overall, the findings seem especially consistent with a retrieval interference view that holds that contextual stimuli can retrieve or signal specific CS–US relations.

Summary

The interference effects described in Table 1 have been explained by a long tradition of associative learning theory. In general, different types of mechanisms have been invoked to explain different interference effects. However, my review suggests that the paradigms have much in common. Contextual stimuli are important in each example of interference and, when information is available, so is the passage of time. Context and time appear to have ubiquitous effects on performance in the interference paradigms.

The paradigms are similar in other ways as well. Performance in each can be accounted for by assuming that interference occurs at the level of performance output rather than during learning. There is actually little in the data to support the common assumption that RI is connected with unlearning Phase 1 or the related assumption that PI is caused by reduced learning of Phase 2. Indeed, the evidence suggests that each example of interference is due at least partly to interference with performance in the target phase. Thus, in the paradigms involving RI, manipulations of context and time can reveal an extant Phase 1 representation; its manifestation in performance has been prevented by Phase 2. Similarly, in the paradigms involving PI, Phase 2 may be acquired but suppressed in performance by Phase 1. As before, the phenomena suggesting this include renewal and spontaneous recovery effects. The various paradigms are affected by context and time, and those effects often suggest the operation of a performance interference mechanism.

The similarity among the paradigms suggests a need for a better theoretical integration. Do current models of conditioning (Mackintosh, 1975; Pearce, 1987; Pearce & Hall, 1980; Rescorla & Wagner, 1972; Wagner, 1978, 1981) provide a good place to begin? One serious problem for these models is that they do not provide a treatment of the effects of long-term retention interval; conditioning theories have ignored the long-term effects of time. It seems clear, however, that no account of interference will be complete without explicitly addressing the effects of retention interval. Current models of conditioning have failed to predict the widespread effects of time in the interference paradigms.

In contrast to their silence on the effects of time, conditioning theories have had a great deal to say about the effects of physical context. One approach has been to assume that the context controls through its associative strength (i.e., its direct association with the US). Often, theories have treated the context as merely a second CS that is present in compound with the target CS (e.g., Mackintosh, 1975; Pearce & Hall, 1980; Rescorla & Wagner, 1972); one implication is that the associative strengths of CS and context should summate in performance. Other theories similarly assume that associative strength in the context may energize performance to the CS (e.g., Konorski, 1967; Wagner & Brandon, 1989), whereas still others have proposed that context–US associations may actually attenuate such responding (Gibbon & Balsam, 1981; Miller & Schachtman, 1985). An emphasis on context–US associations has encountered serious difficulties, however. For example, demonstrable contextual conditioning does not affect responding to the CS in situations in which it is clearly expected to (e.g., Bouton, 1984; Bouton & King, 1986; Bouton et al., 1993; Jenkins & Lambos, 1983); in other cases, contextual control of responding has been shown in the absence of demonstrable associative strength in the context (e.g., Bouton & King, 1983; Bouton & Swartzentruber, 1986; see also Rescorla, Durlach, & Grau, 1985). Other findings, such as the context's control over renewal effects in discrimination reversal learning and in latent inhibition, cannot result from simple excitation or inhibition in a context. In addition, context switches can occasionally decrease responding to a CS even when the two contexts are equally associated with the US (Bonardi, Honey, & Hall, 1990; Hall & Honey, 1989; Honey, Willis, & Hall, 1990). Overall, the results strongly suggest that simple binary associations between a context and a US do not control performance in the interference paradigms.

Recent analyses of the PI paradigms have also emphasized the role of possible context–CS associations: The learning of such an association in Phase 1 could habituate the processing of the CS in memory, making it more difficult for the CS to then enter into a new association in Phase 2 (Wagner, 1978, 1981). This approach has encountered difficulty, however, in that it has been difficult to confirm that habituation is specific to its context. Furthermore, a return to the Phase 1 context can renew PI even when the subject shows clear signs of continued processing of the CS (Peck & Bouton, 1990). The role of binary associations between the context and the CS (as well as context and US) is challenged by existing data.

Another approach could emphasize configural conditioning: Distinct CS–context combinations could themselves acquire excitation or inhibition in the interference paradigms (e.g., Pearce, 1987). However, some phenomena, such as habituation

and excitation conditioned to the CS, appear to transfer well across contexts; such transfer would not be expected if each CS–context combination were distinct. In addition, contextual control of one CS can transfer to new CSs under some conditions (Swartzentruber & Bouton, 1988). Combinations of stimuli that would seem to produce distinct perceptual cues are not especially effective at controlling performance in discrimination reversal learning (e.g., D. R. Thomas et al., 1985). Finally, at least one of the renewal effects reviewed here—the renewal of latent inhibition that occurs on return to the Phase 1 (preexposure) context (e.g., Bouton & Brooks, 1993; Bouton & Swartzentruber, 1989)—lies outside of the scope of existing configural learning models (e.g., Pearce, 1987) because it does not provide an opportunity for the CS–context compound to acquire any associative strength during Phase 1. Like binary context–US and context–CS associations, existing configural learning accounts cannot provide a complete account of the data available on the effects of context in the interference paradigms.

An alternative idea is that contextual stimuli disambiguate or retrieve the current "meaning" of the CS (e.g., Bouton, 1991; Bouton & Bolles, 1985). It has long been recognized that contexts may function to retrieve CS–US associations (e.g., Estes, 1973; Spear, 1973). The possibility that contexts may retrieve associations between other stimuli receives some indirect support from recent research on occasion setting. That research suggests that stimuli can in fact control performance to a target CS in a manner that does not reduce to a simple association between the stimulus and the US, an association between the stimulus and the target CS, or a stimulus–target CS configural cue (e.g., Holland, 1983, 1985; Rescorla, 1985; see especially Holland, 1992). The conditions that allow stimuli to acquire this type of control are not presently well understood. However, stimuli whose onsets precede the target CS (e.g., Holland, 1984, 1985), or are less "salient" than the target even when presented simultaneously (Holland, 1989; see also Jenkins, 1985), appear most likely to acquire this property. Both of these conditions may be satisfied by the long-duration "background" stimuli traditionally identified as contexts, such as physical environment, drugs, emotions, and US aftereffects (e.g., Bouton & Swartzentruber, 1991; Spear, 1978). Furthermore, contexts do appear to take on properties that interact uniquely with discrete Pavlovian occasion setters (Swartzentruber, 1991). Such stimuli may acquire an occasion-setting-like function without differential reinforcement and nonreinforcement of the CS (e.g., Bonardi et al., 1990; Hall & Honey, 1989; Honey et al., 1990). There is increasing evidence that contexts may retrieve CS–US associations.

In summary, current models of conditioning have not provided a satisfactory account of the ubiquitous effects of context, have failed to predict the prevalent effects of retention interval, and have overemphasized the role of learning or storage deficits in the explanation of both RI and PI. Instead, the data suggest that interference may be the general result of a process that occurs at the level of performance or retrieval rather than learning. Information about CS–US relations may be stored and retained from each phase; when interference occurs in animal conditioning, it occurs because the context retrieves conflicting information. This sort of mechanism has been suggested before (Spear, 1978; 1981; see also Bouton, 1991; Miller et al.,

1986; D. R. Thomas, 1981), although it has not been specified in any detail. In the remainder of this article, I attempt to make the approach more explicit.

Context, Time, and Memory Retrieval

A retrieval account of the interference paradigms would begin by assuming that as a result of conditioning, the organism stores a representation that codes information about the CS, the US, and the context in which these stimuli occurred. Once stored, it remains available indefinitely for future retrieval. At the time of retrieval, the representation is activated, and only in this state is it translated into performance. A given representation can be stored along with other, often conflicting, representations of the same CS with other USs. If incompatible representations involving the same CS are activated at the same time, however, they compete with one another for access to performance. I expand on this preliminary sketch by first discussing four basic principles about animal long-term memory and then illustrating how they can be combined to account for several key paradigms.

1. Contextual stimuli guide memory retrieval. Retrieval of a representation depends on the similarity between the conditions present at the time of retrieval and the conditions present at the time of learning. This is an old idea in learning and memory (e.g., McGeoch, 1932), and it has been applied widely and successfully (e.g., Estes, 1973, 1976; Medin, 1976; Spear, 1973, 1978; Tulving, 1974). One can assume that retrieval of a representation depends on the degree of match between the test context and the learning context; retrieval therefore decreases as the context changes between learning and testing. One implication, of course, is that "forgetting" can result from simple retrieval failure. Forgotten memories are not necessarily lost from the long-term memory store; they may be recovered if the subject is returned to a closer facsimile of the original training context. Along with Spear (1976, 1978), I assume that this can occur if the animal is returned to the original context or is presented with other cues that were featured in that context, as in various memory "reactivation" treatments (e.g., Gordon, 1981; Spear & Parsons, 1976).

How exactly does the context function as a retrieval cue? I assume that CS and context are stored so as to form an "interactive" CS–context cue (e.g., Humphreys et al., 1989) or control element containing information about the context, CS, and US (Estes, 1976; Medin, 1976; Medin & Reynolds, 1985; see also Holland, 1992). The interactive cue functions as an AND gate that requires activation of both the context and CS inputs for activation of the representation as a unit. I have already noted that binary context–US and context–CS associations do not explain the effects of context in the interference paradigms. Furthermore, a representation that codes context, CS, and US is necessary to explain conditional discriminations of the type encountered in the contextual control of discrimination reversal learning (e.g., Bouton & Brooks, 1993; D. R. Thomas et al., 1981). Interactive CS–context memory cues are similar to CS–context configural cues (e.g., Pearce, 1987). However, by placing the interaction between CS and context within a memory structure, one can avoid many of the problems noted earlier that are connected with assuming unique *perceptual* cues. In addition,

by assuming that *time* provides part of the context cue (see next section), the present approach addresses the effects of retention interval. Nonetheless, the approach still has difficulty accounting for the fact that a context's ability to control responding to one CS can sometimes transfer to another CS (Swartzentruber, 1993; Swartzentruber & Bouton, 1988). The transfer issue is also unresolved in the occasion-setting literature (e.g., Holland, 1992; Lamarre & Holland, 1987; Wilson & Pearce, 1990). In the present scheme, the joint presence of CS and context is required for activation of the corresponding memory unit.

2. Time is a context. As time elapses following learning, the background context provided by both internal cues (e.g., hormonal, neurochemical) and external cues (e.g., recent stimuli, physical background context) are likely to change (e.g., Spear, 1978). To begin to account for the effects of long-term retention interval, one may therefore note that the passage of time itself indirectly produces a gradually changing context. Once again, similar views have been taken before (e.g., Gordon, 1981; Mensink & Raaijmakers, 1988; Spear, 1978), although they have not been assimilated in the conditioning literature. According to this view, forgetting that occurs over a retention interval is merely another case of retrieval failure that results from a mismatch between the *temporal* learning and testing contexts. The effects of a retention interval or a physical context switch are thus fundamentally the same; both can cause retrieval failure by moving the subject out of the context with which a stored representation has been encoded. In effect, time provides a kind of context.

The view that retention intervals cause forgetting because they change the context was tentatively challenged by Riccio, Richardson, and Ebner (1984). They argued that generalization gradients tend to flatten over time; any flattening of the gradient around a contextual retrieval cue could offset the effects of a change of context. This paradox raises an empirical question: How much do gradients around retrieval cues really flatten over time? Although a complete review of the generalization literature is beyond the scope of this article, two points can be made. First, the flattening of gradients over time is often not as dramatic as the term *flattening* may imply. For example, data on discriminated operant responding in pigeons, perhaps the most systematic data available, suggest that gradients broaden to some extent over a 24-hr period (e.g., Moye & Thomas, 1982; D. R. Thomas & Burr, 1969; D. R. Thomas & Lopez, 1962). However, they do not flatten further over longer intervals (D. R. Thomas & Lopez, 1962; D. R. Thomas, Ost, & Thomas, 1960), and the pigeon still appears to retain considerable stimulus control. To put it informally, although the pigeon may come to confuse similar shades of green, it does not confuse green with yellow. The second point is that few experiments have addressed the shape of gradients around contextual stimuli that function to control responding to CSs that are embedded in them. However, the results of several that have tested this sort of context effect suggest that contextual control is strong, and perhaps undiminished, at intervals of 21 days and more (Bouton & Brooks, 1993, Experiment 4; Peck & Bouton, 1990, Experiment 2; D. R. Thomas et al., 1984, Experiments 1 and 2). There is little evidence that contextual control of the type under discussion is lost significantly over time. It would therefore be

premature to reject the idea that the passage of time causes forgetting because it changes the context.

As I illustrate shortly, the idea that time provides a context can provide a fairly powerful explanation of retention interval effects on performance in Pavlovian interference. Furthermore, because the present approach so specifically connects temporal and physical context, it makes previously overlooked but testable predictions: Manipulations of context and retention interval should have similar effects. Indeed, if context switches and retention intervals are functionally equivalent, then their effects should be additive.

3. Different memories depend differentially on context. The literature on animal memory supports the assertion that time and physical context can be described in the same terms. It also supports another proposition at the same time. Different types of memories appear to differ in their sensitivity to manipulations of physical context. And importantly, a given memory's sensitivity to physical context also predicts its sensitivity to time. Different types of memories vary in their sensitivity to manipulations of physical and temporal context.

It is now reasonably well established that excitatory aversive conditioning is relatively stable over changes of physical context (e.g., Bouton & King, 1983; Bouton & Swartzentruber, 1986; Hall & Honey, 1989; Kaye et al., 1987; Lovibond et al., 1984) and long (e.g., multiple-week) retention intervals (e.g., Bouton & Peck, 1992; Gleitman & Holmes, 1967; Hendersen, 1978, 1985; Hoffman, Fleshler, & Jensen, 1963). Animals do not readily forget fear experiences with changes of context or time. Similarly, excitatory appetitive (food) conditioning is often unaffected by a context switch (e.g., Bouton & Peck, 1989; Kaye & Mackintosh, 1990; Peck & Bouton, 1990, Experiment 3), and it is also stable over a 28-day retention interval (Bouton & Peck, 1992). These observations do not necessarily imply that excitation is completely independent of context for retrieval. Details of excitatory representations are almost certainly lost over time (e.g., Hendersen, 1985; D. R. Thomas, 1981), and under some conditions the magnitude of both appetitive CRs (Hall & Honey, 1989; Peck & Bouton, 1990, Experiment 2) and aversive CRs (Balaz, Capra, Hartl, & Miller, 1981; Hall & Honey, 1990) have been reduced by a change of context. However, compared with the other types of representations learned in the Pavlovian interference paradigms, retrieval of shock and food excitation is relatively stable over physical context and time.

The stability of excitation over physical and temporal context appears to contrast with the instability of conditioned inhibition. Hendersen (1978) and D. A. Thomas (1979) have shown that fear inhibition conditioned with at least two procedures was lost in 25 days; excitation remained unchanged over the same interval. Inhibition may also be attenuated by a change of physical context. In generalization tests with pigeons after intradimensional discrimination training, Hickis, Robles, and Thomas (1977) found that peak shift (a shift in the peak of the gradient from S+ in a direction away from S−) depended on S+ and S− being conditioned in the same context. Testing was conducted in the S+ (but not the S−) context; the data are therefore consistent with the view that inhibition to S− (the process on which peak shift relies) was relatively specific to its context. Data with pigeons reported by Kaplan and Hearst (1985) can be interpreted in the same way. In addition, recent research

with rats in both aversive conditioning (Peck, 1993) and appetitive conditioning (Bouton & Nelson, 1993) is beginning to suggest that inhibition may be relatively context specific. In contrast to excitation, inhibition may be more sensitive to changes in physical context and time.

From a retrieval perspective, latent inhibition is also relatively dependent on physical context for retrieval: As reviewed earlier, the effects of CS preexposure are readily attenuated when the context is switched between preexposure and conditioning. (Kaye et al., 1987, showed that the differential context sensitivity of latent inhibition and aversive excitation is not an artifact of the different procedures usually used to test excitation and latent inhibition; when both were assessed with a resistance to appetitive reinforcement procedure, latent inhibition was more disrupted by a context switch than was aversive excitation.) Furthermore, latent inhibition is also lost over moderate retention intervals (Hall & Minor, 1984; Kraemer & Roberts, 1984; McIntosh & Tarpy, 1977). Like conditioned inhibition but in contrast to conditioned excitation, latent inhibition is sensitive to changes in physical and temporal context.

These differences in sensitivity to temporal and physical context change are large enough that no approach to the Pavlovian interference paradigms can afford to ignore them. They do not seem to be anticipated by models of context and human memory (e.g., Humphreys et al., 1989; Mensink & Raaijmakers, 1988; Raaijmakers & Shiffrin, 1981). Researchers in the area of human memory have actually discussed the possibility that the forgetting function is surprisingly invariant over training conditions (e.g., Slamecka & McElree, 1983; see also Loftus, 1985). It may be relevant to bear in mind, however, that experiments on human memory usually investigate memory for verbal material that is relatively "trivial [and] affect-free" (Hendersen, 1985, p. 43). The picture may be somewhat different for the motivationally significant material involved in animal laboratory experiments (and some real-world human experiments).

One factor that is likely to determine a memory's sensitivity to context is its functional, or adaptive, value. As Devenport (1989) and Hendersen (1985) have noted, it is costly to forget events that are biologically significant. Thus, excitatory memories may be retrieved over time and physical context because they involve important events and therefore have general adaptive value. In some cases, however, forgetting may be beneficial. Retrieval of some events may be dependent on context because they are intrinsically variable over space and time. For example, the palatability of certain butterflies depends on their consumption of milkweed, which makes them bitter. If milkweed is distributed in patches over space and in time, then it may benefit a predator to forget an unpalatable meal when a butterfly is encountered in a new place or at some later time (M. Speed, personal communication, April 1990). Inhibition, the memory that a CS means no US, is similarly treated by the memory system as if it is inherently variable over space and time. The system seems to recognize that it is risky to accept the null hypothesis (i.e., that a CS means no US) on the basis of a single sample from a particular location or time.

A second factor that could affect a memory's sensitivity to context is whether conditions at the time of learning encourage the subject to code or "integrate" contextual information with other features of the stored representation (cf. Baddeley, 1982).

When the human subject is instructed to code the environmental context along with words he or she memorizes, retrieval of those words may become more context dependent (Eich, 1985). What conditions encourage an animal to code context in a conditioning experiment? One possibility occurs when the CS takes on a new "meaning," as it does in the second phase of an interference paradigm. Here, the context is no longer necessarily incidental to the task; if the background has changed at all, it can signal a change in meaning of the CS. The context may thus be coded as a feature of the second representation (e.g., the CS means no shock here or now). Consistent with this possibility, Swartzentruber and Bouton (1992) found that excitatory fear performance was attenuated by a context switch if conditioning was preceded by a CS preexposure phase; as usual, excitation was otherwise not affected by the context switch. Excitation was more context dependent when it was acquired as the CS's second meaning. The context may be more important for retrieval of a CS's second representation.

In principle, a representation's sensitivity to context can be assessed by testing the effects of retention interval and context switch manipulations. Thus, it is possible to establish sensitivity to context empirically and use that observation to make a priori predictions about interference. In this manner, the retrieval approach can make testable predictions about performance in the Pavlovian interference paradigms. Research on memory for emotionally significant material suggests that memories will differ in their sensitivity to the effects of context and time.

4. Interference occurs at output rather than input. Each of the interference paradigms involves the storage of at least one representation from each phase. The evidence reviewed earlier suggests that each is at least partly retained through Phase 2. It is possible that Phase 2 learning involves some destruction of Phase 1 information and that Phase 1 learning likewise reduces storage in Phase 2. However, the previous review indicates that interference at performance output is also involved (see also Hall, 1991). It is most parsimonious to assume for the present that interference occurs entirely at retrieval.

As described earlier, the activation of each representation would occur according to the similarity between the present context and the encoded context cue. If incompatible representations are activated, they would compete for limited space in working memory (cf. Wagner, 1978), or their presence could reduce either the activation available for the target memory (e.g., J. R. Anderson, 1983; Wagner, 1981) or the probability with which the target representation is sampled (Mensink & Raaijmakers, 1988). By any of these mechanisms, the presence of conflicting representations would reduce a target representation's access to performance. The approach thus acknowledges two sources of forgetting: retrieval failure resulting from a change of context and interference caused by the activation of conflicting representations.

Three Applications

When put together, Principles 1–4 can provide a reasonably complete account of performance in the interference paradigms. For further illustration and development, I now consider their application in extinction, counterconditioning, and

latent inhibition, three of the core paradigms that represent varying degrees of retroactive through proactive interference.

Extinction

During conditioning, the animal is expected to learn and store a representation that codes the context, CS, and US. During subsequent extinction training, the animal gradually stores a new representation that codes "no US" and is thus analogous to a representation of inhibition (e.g., Konorski, 1967; Pearce, 1987; Wagner, 1981). The original representation is not unlearned; it is retrieved on each extinction trial depending on the similarity of the present context to the previous one. As the competing extinction representation is acquired, however, it is also retrieved on each trial, and it begins to interfere with conditioning. If storage of the extinction representation were to increase incrementally, there would be an orderly decrease in performance over extinction trials. At the end of extinction, the CS would be included in two conflicting representations; in this sense, its meaning would be ambiguous (e.g., Bouton, 1988; Bouton & Bolles, 1985).

On this account, extinction performance depends crucially on the retrieval of the representation of extinction. Unstable performance is expected with an extinguished CS because extinction (inhibition) depends importantly on context for retrieval. Because retrieval of extinction is more context dependent than conditioning, a change in either the physical context or the temporal context will reduce the retrieval of extinction while having less impact on the retrieval of conditioning. The result is a restoration of conditioned performance; context switches and retention intervals will result in renewal and spontaneous recovery. This approach can accommodate much of what is known about the effects of context in extinction. In addition, spontaneous recovery is viewed simply as the renewal effect that occurs when the subject is removed from the temporal extinction context (Bouton, 1988, 1991; Bouton & Swartzentruber, 1991). Renewal and spontaneous recovery both result from a failure to retrieve extinction.

The assertion that extinction (inhibition) is relatively easy to disrupt by changing the temporal or physical context has not been a part of other discussions of retrieval effects in the interference paradigms (e.g., Spear, 1981). It is, however, reminiscent of the ideas of Pavlov (1927). Pavlov assumed that inhibition was acquired in extinction and that it was more labile than excitation. The present position accepts this notion but attributes it to a specific *memory* mechanism: Inhibition is subject to retrieval failure. The new view makes the testable prediction that a retrieval cue that activates the memory of extinction should attenuate spontaneous recovery if it is presented during testing. Brooks and Bouton (1993) have recently confirmed the prediction. In their experiments, a brief cue was introduced and correlated with extinction of a target CS. When the cue was presented prior to a subsequent spontaneous recovery test, recovery was attenuated. The attenuation depended on the cue's specific relation to extinction; in addition, the cue did not have demonstrable associative properties (excitation or inhibition) at the time of the test. Brooks and Bouton concluded that the cue retrieved a memory of extinction and that spontaneous recovery may therefore occur because of a failure to retrieve extinc-

tion. The present framework proposes that the same failure occurs with a physical context switch; it therefore predicts that a retrieval cue will likewise attenuate the renewal effect. The approach provides a clear integration of context and time effects on extinction performance, makes new predictions, and has a demonstrated heuristic value.

Counterconditioning

It is possible to use the same principles to account for the paradigms that intermix RI and PI. In counterconditioning, the subject again stores representations corresponding to two phases; as before, performance depends on how well each is retrieved. PI would come about because of retrieval of Phase 1; RI would come about because of retrieval of Phase 2. As in extinction, it is not necessary to assume unlearning of Phase 1 and, similarly, it is not necessary to assume that Phase 1 interferes with the learning of Phase 2.

At least two approaches can then be taken to account for the effects of time and context in this paradigm. One approach (Bouton & Peck, 1992) builds directly on the preceding account of extinction: Counterconditioning is merely a case of extinction in which the CS is also associated with a new US. For example, in the second phase of aversive–appetitive transfer, the subject learns that the CS is no longer associated with shock (CS–no shock, or shock inhibition) at the same time it also learns that the CS is associated with food. Activation of CS–no shock and CS–food would interfere with CS–shock; conversely, activation of CS–shock would interfere with CS–food. Because retrieval of inhibition is sensitive to both time and context, spontaneous recovery (Bouton & Peck, 1992) and renewal effects (Peck & Bouton, 1990) would again follow. As time elapses following Phase 2, CS–no shock would become less retrievable, leaving CS–shock to reemerge and interfere with CS–food. (Because competition occurs at retrieval, such a mechanism could imply, but does not require, the absolute recovery of Phase 1 performance observed by Bouton & Peck, 1992.) Similarly, if the animal is returned to the Phase 1 context after CS–food conditioning in a second context, CS–no shock would suffer from retrieval failure, leaving CS–shock free to reemerge in performance and interfere with CS–food (Peck & Bouton, 1990). This account synthesizes the effects of time, context, and interference represented in counterconditioning by simply building on the account of extinction.

An alternative account could ignore the role of a context-sensitive representation of inhibition. The animal may simply associate the CS and shock in Phase 1 and CS and food in Phase 2; performance would simply depend on the relative retrieval of these two representations. Spontaneous recovery effects could then be explained by assuming that the subject forgets which of the two representations occurred more recently (e.g., Gleitman, 1971; Mackintosh, 1974; Spear, 1971). Retrieval of the separate memories could decline over time according to functions that would make the more recent memory undergo a larger net loss (e.g., J. R. Anderson, 1983; Mensink & Raaijmakers, 1988). Such an approach can simulate much of the data on verbal learning (see Mensink & Raaijmakers, 1988). However, it is not clear that it would handle the data from the animal paradigms. For example, this sort of mechanism would not readily explain why re-

sponding can return to levels as high as asymptotic responding when recovery is tested after extinction (e.g., Bouton & Brooks, 1993; Brooks & Bouton, 1993; Rescorla & Cunningham, 1978). Perhaps more important, the approach would fail as a general approach to Pavlovian interference because, as reviewed earlier, there are cases in which PI *decreases,* rather than increases, over time (e.g., Kraemer & Roberts, 1984). In the next section, I show that such results are easier to accommodate by recognizing that different types of representations may be differentially sensitive to time. The view that counterconditioning involves a context-sensitive representation of inhibition may be more consistent with a general account of the Pavlovian interference paradigms.

Latent Inhibition

The same principles could be extended to other paradigms in which the focus is exclusively PI. In latent inhibition, it is necessary for a retrieval approach to assume that the subject learns something about the CS during simple CS preexposure (see Bouton, 1991). Furthermore, whatever is learned must be incompatible with inhibition because CS preexposure interferes proactively with the acquisition of conditioned inhibition (e.g., Rescorla, 1971). One possibility is that the animal may learn that the CS is "insignificant" during preexposure; this could interfere with either CS-US or CS-no US, which are both motivationally significant. If the animal learns something about the CS in Phase 1, then latent inhibition would reduce to a case of counterconditioning: During Phase 2, the animal learns the new CS-US association, and it may also learn that the CS is no longer insignificant. As in counterconditioning, interference with Phase 2 conditioning would occur because of retrieval of Phase 1 information.

This approach to latent inhibition has several implications. First, because "insignificance" is postulated to be sensitive to context and time, the approach accommodates a loss of interference that occurs when either a context switch (e.g., Hall & Channell, 1985) or a retention interval (e.g., Hall & Minor, 1984) occurs between preexposure and conditioning. Furthermore, if preexposure and conditioning are conducted in different contexts, a return to the context of preexposure will produce a renewal of interference with conditioned performance by reretrieving insignificance (e.g., Bouton & Brooks, 1993; Bouton & Swartzentruber, 1989).

There are also novel implications for the effects of time following Phase 2. Recall that subjects may forget which phase came first as time elapses following Phase 2; as discussed earlier, this approach implies an increase in PI over time (e.g., Gleitman, 1971; Mackintosh, 1974; Mensink & Raaijmakers, 1988). By contrast, if insignificance is more dependent on time than is the excitation learned during Phase 2, this case of PI is expected to decrease, rather than increase, over time. As reviewed earlier, this is the outcome observed in several experiments (e.g., Kraemer & Roberts, 1984; Kraemer & Spear, 1992). Kraemer and Roberts proposed a similar explanation.

Still more interesting predictions are possible if one acknowledges the possible role of an "inhibition of Phase 1" process analogous to the one suggested in counterconditioning. When I reviewed latent inhibition earlier, I noted a discrepancy in some

of the published effects of retention interval after Phase 2: Although some data suggest that a retention interval after Phase 2 conditioning can decrease interference (e.g., Kraemer & Roberts, 1984), other results suggest the opposite (i.e., that a retention interval after Phase 2 can actually increase interference; Spear et al., 1965; Spear & Spitzner, 1967). The present approach suggests that opposite outcomes may occur in experiments that test different retention intervals. If the inhibition of Phase 1 decreased more rapidly than the representation of Phase 1 (in a manner consistent with the view that inhibition is more labile than the process it inhibits), the approach would predict a biphasic performance function as time elapses following Phase 2. There would be an initial increase in interference (as inhibition is lost), followed by the decrease in interference (described earlier) that results from the loss of the Phase 1 representation. Consistent with this pattern, Spear et al. (1965) found an increase in interference with a 1-day retention interval, whereas Kraemer and his colleagues obtained a decrease in interference with retention intervals of at least 7 days (Kraemer et al., 1988, 1991; Kraemer & Ossenkopp, 1986; Kraemer & Roberts, 1984; Kraemer & Spear, 1992). More parametric research is needed, but a retrieval account of latent inhibition may go a surprising distance in explaining the complex effects of time and context that have been reported in this paradigm.

Conclusion

By building on four propositions about animal memory retrieval, a simple, integrated approach can account for the different interference effects that are represented in extinction, counterconditioning, and latent inhibition. It would not be difficult to show that the approach can be further extended to account for the other paradigms of Table 1. In each case, retrieval of information from one phase could produce interference with retrieval from the other phase. The present approach extends previous suggestions that interference in animal conditioning may result from the retrieval of conflicting information (e.g., Bouton, 1991; Miller et al., 1986; Spear, 1981; D. R. Thomas, 1981). It provides more detail about the memory mechanisms, argues explicitly that retention interval and physical context switches should have similar effects, and proposes that retrieval of different types of representations may depend differentially on context (both physical and temporal). The approach also bears some resemblance to theories of interference in human memory (e.g., Mensink & Raaijmakers, 1988) but differs in many details, including the assumption of differential sensitivity to context. A retrieval approach to the animal conditioning phenomena is highly consistent with the data and, as illustrated here, has heuristic value. Memory retrieval processes appear to hold considerable promise for integrating the effects of time and context across the Pavlovian interference paradigms.

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