

Local context and the comparator hypothesis

ROBERT C. BARNET, NICHOLAS J. GRAHAME, and RALPH R. MILLER
State University of New York, Binghamton, New York

“Comparator” accounts of associative conditioning (e.g., Gibbon & Balsam, 1981; Miller & Matzel, 1988) suggest that performance to a Pavlovian CS is determined by a comparison of the US expectancy of the CS with the US expectancy of general background cues. Recent research indicates that variation in the excitatory value of cues in the local temporal context of a CS may have a profound impact on conditioned responding to the CS (e.g., Kaplan & Hearst, 1982), implicating US expectancy based on local, rather than overall, background cues as the critical comparator term for a CS. In two experiments, an excitatory training context attenuated responding to a target CS. In Experiment 1, the context was made excitatory by interspersing un signaled USs with target CS-US trials. In this case, posttraining extinction of the conditioning context restored responding to the target CS. In Experiment 2, the target CS's local context was made excitatory by the placement of excitatory “cover” stimuli in the immediate temporal proximity of each target CS-US trial. In this experiment, posttraining extinction of the proximal cover stimuli, not extinction of the conditioning context alone, restored responding to the target CS. An observation from both experiments was that signaling the otherwise un signaled USs did not appear to influence the associative value of the conditioning context. The results are discussed in relation to a local context version of the comparator hypothesis and serve to emphasize the importance of local context cues in the modulation of acquired behavior. Taken together with other recent reports (e.g., Cooper, Aronson, Balsam, & Gibbon, 1990; Schachtman & Reilly, 1987), the present observations encourage contemporary comparator theories to reevaluate which aspects of the conditioning situation comprise the CS's comparator term.

In a typical Pavlovian conditioning experiment, a conditioned stimulus (CS), such as a light or tone, is paired with an unconditioned stimulus (US), such as food or foot-shock. The consequence of these pairings is commonly assumed to be the establishment of a CS-US association, and learning is said to occur when the CS elicits a conditioned response. However, acquisition of conditioned responding to a target CS is often impaired if un signaled USs are interspersed among the CS-US pairings during the conditioning session. This response deficit, induced by un signaled USs, has been demonstrated in a variety of species, including rats (e.g., Ayres, Benedict, & Witcher, 1975; Rescorla, 1968, 1972, 1984), pigeons (e.g., Durlach, 1983, 1986, 1989; Gamzu & Williams, 1973; Jenkins, Barnes, & Barrera, 1981), and humans (e.g., Champion, 1961). Thus, at the behavioral level,

there is good agreement that interspersed un signaled USs interfere with conditioned responding to the target CS.

At the theoretical level, there is much less agreement about the consequences of these un signaled USs. Durlach (1983) and Rescorla (1984), for example, have argued that the detrimental effect of the un signaled USs reflects a deficit in learning about the target CS that occurs because the training context blocks target CS acquisition. According to this blocking-by-context view, the un signaled USs enhance the associative strength of the static contextual cues. Then, during target CS-US pairings, the excitatory context blocks the target CS from accruing associative strength (e.g., Tomie, 1981). This can be viewed as a form of selective learning in which cues present when a US is delivered (e.g., CS and contextual cues) compete for associative strength and thus behavioral control (i.e., Rescorla, 1972; Rescorla & Wagner, 1972).

An alternative view of the effects of un signaled USs is provided by Gibbon and Balsam's (1981; Gibbon, 1977) scalar expectancy theory (SET). Although these investigators agree that the effect of un signaled USs is to enhance the associative strength of the context, they diverge from the selective learning view by assuming that the associative outcome of target CS-US pairings proceeds independently from the associative value of the context. In this view, conditioned responding is determined by a comparison of the expectancy of the US during the entire conditioning situation (“C” or cycle time, which is the average delay between USs) with the expectancy of the US during the CS (“T” or trial time, which is the average

The data reported here formed part of a thesis submitted by the first author to the State University of New York at Binghamton in partial fulfillment of the requirements for the master of arts degree. R.C.B. wishes to acknowledge the support and advice of his committee members, Ralph Miller, Stanley Scobie, and Norman Spear, during all stages of this investigation. Support for this research was provided by National Institute of Mental Health Grant 33881 and the SUNY-Binghamton Center for Cognitive and Psycholinguistic Sciences. R.C.B. was supported by a Natural Sciences and Engineering Research Council of Canada postgraduate scholarship. Thanks are due to Hua Yin for comments on an earlier version of the manuscript and to Douglas Dufore and Gerard Newcomer for assistance in data collection. Requests for reprints should be addressed to R. R. Miller, SUNY-Binghamton, Binghamton, NY 13902-6000.

delay between CS onset and the US). Specifically, conditioned responding is predicted when the C/T ratio exceeds a threshold value of approximately 2.0. According to SET, un signaled USs decrease the cycle time, thereby lowering the C/T ratio, and consequently attenuate responding to the CS.

A conceptually similar alternative to the selective learning view is provided by Miller and Schachtman's (1985) comparator hypothesis (see Miller & Matzel, 1988, p. 80 for a discussion of the differences between SET and the comparator hypothesis). This view concurs with SET in suggesting that conditioned responding is not determined by the absolute associative strength of the target CS, but is determined instead by a comparison of the associative value of the target CS to the associative value of other cues present during target CS training (i.e., comparator stimuli). According to the comparator hypothesis, deficient excitatory responding to the target CS will be observed when the associative value of the comparator stimulus (e.g., context) is large relative to the associative value of the target CS. Accordingly, un signaled USs would be expected to promote context-US associations that would be large relative to the target CS-US association and, consequently, deficient excitatory responding to the target CS would be predicted. The positions taken by Gibbon and Balsam (1981) and Miller and Schachtman (1985) can be referred to as the "comparator" view, because the US expectancy or associative value of the target CS is thought to be compared to the US expectancy or associative value of the background cues.

The comparator hypothesis uniquely assumes that when the comparator stimulus (e.g., context) is relatively high in associative strength due to un signaled USs, manipulations such as posttraining context extinction, which are designed to degrade the associative value of the comparator stimulus, should promote a relative increase in the associative value of the target CS. This relative increase in value should promote recovery of responding to the target CS. Consistent with these assumptions of changes in relative associative strength, posttraining extinction of an excitatory conditioning context has been observed to partially restore responding to a target CS that is deficient as a response elicitor due to US preexposure (i.e., Matzel, Brown, & Miller, 1987). The fact that US preexposure results in deficient responding to a target CS is consistent with the predictions of both the selective learning view and the comparator hypothesis. However, the finding that posttraining extinction of the conditioning context results in recovery of responding to the target CS is predicted only by the comparator hypothesis and is inconsistent with the selective learning view. According to the selective learning account of the US preexposure effect, the target CS should have been deficient in its associative strength at the time of context extinction because the previously excitatory context blocked target CS acquisition. Thus, with or without posttraining context extinction, the target CS should be deficient in associative strength and deficient responding to the target CS should occur.

One common aspect of the comparator notions proposed by Gibbon and Balsam (1981) and by Miller and Schachtman (1985) is that the effective comparator term arises from static apparatus cues (i.e., global context) within the conditioning session(s). In other words, the US expectancy or associative strength of the context, which modulates responding to a target CS, is presumed to arise from some internal averaging of the USs that occur throughout the entire conditioning episode. Little attention has been devoted to the investigation of local, rather than global, aspects of the conditioning situation in the modulation of responding to a Pavlovian CS.

Kaplan and Hearst (1982) have suggested that the local training context may play an important role in the emergence of conditioned responding. These authors, using trace conditioning in autoshaping, reported that a CS presented in a nonexcitatory or inhibitory local context acquired substantial excitatory response potential. On the other hand, a CS presented in an excitatory local context did not gain appreciable response potential. These findings suggest that the associative value of the local context, as opposed to (or in addition to) the global training context, in which a CS is embedded, may play an important role in the expression of acquired information. Similar types of effects have been reported by Schachtman and Reilly (1987; see also Reilly & Schachtman, 1987), who defined local context as "the precise stimulus conditions in which the target CS is embedded during training" (p. 344). Moreover, in the latter study, these authors argued that the US expectancy in the local context, *rather* than the US expectancy of the entire conditioning session, serves as the critical basis for comparison with the target CS. In this view, manipulations designed to influence the associative value of the context (e.g., presenting un signaled USs in the intertrial intervals) will modulate responding to the target CS only to the extent that those manipulations influence the associative value of the target CS's local context.

The primary goal of the present research was to evaluate the application of Schachtman and Reilly's (1987; Reilly & Schachtman, 1987) local context view to the comparator hypothesis and to test the emergent predictions. In Experiment 1, we assessed the effect on responding to the target CS of un signaled USs interspersed with target CS-US trials and the subsequent extinction of the target CS's training context. On the basis of prior research in which un signaled USs preceded target CS-US pairings (Matzel et al., 1987), we expected that the presence of un signaled USs both before and during target CS training would result in deficient responding to the target CS and that subsequent extinction of the target CS's training context would restore responding to the target CS. Although such a pattern of findings would be consistent with the assumptions of the comparator hypothesis, it would not determine whether any observed modulation of responding to the target CS was mediated by "global" or "local" attributes of the conditioning situation. Presenting un signaled USs in the intertrial intervals and extinguishing the training context after target CS training could influence the associative value of

the local context, the global context, or both. In Experiment 2, the effect of variations in the excitatory value of local context on responding to the target CS was directly evaluated by using a modification of the cover stimulus preparation from Experiment 1.

EXPERIMENT 1

In Experiment 1, intertrial USs were presented in the training context before and during target CS training for some animals and were not presented in the training context for others. Some of the animals that were scheduled to receive intertrial USs in the training context had those USs signaled by a "cover" stimulus. Durlach (1983) has shown that signaling intertrial USs with a cover stimulus can promote responding to a target CS that is deficient as a response elicitor when the intertrial USs are un signaled. The remaining animals that were scheduled to receive the intertrial USs in the training context experienced those USs un signaled. These latter animals, exposed to un signaled USs, were distinguished by whether or not the training context was extinguished following target CS training. To the extent that un signaled USs presented in the training context attenuate responding to the target CS, the comparator hypothesis assumes that subsequent extinction of the training context should degrade the value of the target CS's comparator stimulus, and thereby promote recovery of responding to the target CS.

Method

Subjects

The subjects were 24 male and 24 female, naive Sprague-Dawley rats. Weight ranges were 320-440 g for males and 280-410 g for females. Each animal was assigned to one of four groups ($n = 12$), counterbalanced for sex. The animals were individually housed in standard hanging stainless steel wire-mesh cages in a vivarium maintained on a 16:8-h light:dark cycle. Experimental manipulations occurred near the midpoint of the 16-h light cycle. The animals were allowed free access to Purina Laboratory Chow in their home cages. One week prior to the initiation of the study, all the animals were progressively deprived of water. By Day 1 of the study, access to water in the home cage was limited to 10 min per day, and was thereafter provided 18-22 h prior to any treatment scheduled for the following day. All the subjects were handled three times per week for 30 sec, from weaning until the initiation of the study.

Apparatus

Three types of animal chambers were used. Chamber Y (of which there were six copies) was rectangular in shape and measured $22.75 \times 8.25 \times 13.0$ cm ($l \times w \times h$). The walls and ceiling were constructed of clear Plexiglas. The floor was constructed of stainless steel rods that were 0.48 cm in diameter and 1.5 cm apart, center to center. The rods were connected by NE-2 neon bulbs, which allowed a constant-current footshock to be delivered by means of a high-voltage ac circuit in series with a 1.0-M Ω resistor. Six copies of Chamber Y were each contained in a sound- and light-attenuating environmental isolation chest. Chamber Y could be brightly illuminated by a flashing (0.17 sec on/0.17 sec off) 25-W bulb; it was otherwise illuminated by a 2-W (nominal at 120 VAC) houselight driven at 56 VAC. The houselight was turned off whenever the 25-W bulb was being flashed. Both bulbs were mounted on an in-

side wall of the environmental isolation chest, approximately 30 cm from the animal chamber.

Chamber Z (of which there were six copies) was a 25.5-cm-long box in a truncated-V shape. This chamber was 28 cm high and 21 cm wide at the top, narrowing to 5.25 cm wide at the bottom. The ceiling was constructed of clear Plexiglas and the narrow-end walls were constructed of black Plexiglas. The floor and the 25.5-cm-long side walls were constructed of sheet metal. The floor consisted of two 25.5-cm-long parallel metal plates, each 2 cm wide, with a 1.25-cm gap between them. A constant-current footshock could be delivered through the metal walls and floor of the chamber. Six of these chambers were each contained in a light- and sound-attenuating environmental isolation chest. Chamber Z could be brightly illuminated by a flashing (0.17 sec on/0.17 sec off) 100-W bulb; it was otherwise illuminated by a 7.5-W (nominal at 120 VAC) houselight driven at 56 VAC. The houselight was turned off whenever the 100-W bulb was being flashed. Both bulbs were mounted on an inside wall of the environmental isolation chest, approximately 30 cm from the animal chamber. Light entered the animal chamber primarily by reflection from the roof of the environmental chest. These light intensities roughly matched those in Chamber Y, because of differences in the opaqueness of the chamber walls.

Chambers Y and Z were each equipped with a water-filled lick tube. When inserted, the lick tube protruded 1 cm into a cylindrical drinking recess that was set into one of the narrow Plexiglas walls of the chamber, with its axis perpendicular to the wall. The recess was equidistant from the chamber's walls, and was centered 3.5 cm above the chamber's floor. Each recess was 5.0 cm deep and 4.5 cm in diameter. An infrared photobeam, 0.5 cm in front of the lick tube, was used to determine when the subjects had their heads inserted into the drinking recess. All chambers were equipped with a 45- Ω speaker mounted on the interior back side of each environmental isolation chest, which could deliver a complex tone (3000 and 3200 Hz), 8 dB(C) SPL above the background noise of 74 dB(C).

In addition, a third type of chamber, designated as *context long* (of which there were 12 copies), was used for exposing control animals to un signaled USs. These chambers were designed to differ appreciably from Chambers Y and Z. The chambers were long and rectangular in shape and measured $47 \times 8.5 \times 57$ cm ($l \times w \times h$). The end walls were constructed of opaque Plexiglas and the long walls were constructed of aluminum. The floor was constructed of stainless steel rods, 0.64 cm in diameter, each placed parallel to the long aluminum walls. The separation between rods was 1.8 cm, center to center. The rods were connected by NE-2H neon bulbs in series with a 1-M Ω resistor, and could deliver a constant-current footshock. Context long was housed in a well-lighted (160-W of fluorescent illumination) experimental room.

Procedure

The critical aspects of the procedure are summarized in Table 1.

Acclimation. Acclimation to the chambers was conducted in *context train* (the training context) and *context test* (the testing context) on Days 1-3. For half of the animals in each group, the training context was Chamber Y and the testing context was Chamber Z. For the other half of the animals in each group, the training and testing contexts were Chambers Z and Y, respectively. On Day 1, the subjects were acclimated to context test for 60 min, during which time the water-filled lick tubes were available. Context test later served as an associatively neutral context for testing of the target CS. On Days 2 and 3, all the subjects were acclimated to context train for 60 min, during which time the water-filled lick tubes were available.

Cover stimulus training (Phase 1). Following acclimation, the lick tubes were removed from all chambers. Cover stimulus train-

Table 1
Design Summary for Experiment 1

Group	Treatment			
	Phase 1 Context Train Days 4-7	Phase 2 Context Train Days 8-9	Phase 3 Days 10-15	Test* Days 18-20
ACQ:HC	—	T+	HC	T, CONT, L
DISTAL:HC	L±	T+/L±	HC	T, CONT, L
UNS:HC	+	T+/+	HC	T, CONT, L
UNS:CONT—	+	T+/+	CONT—	T, CONT, L

Note—CONT = context train; + = US; — = no US; ± = partial reinforcement; L = light; T = tone; / = interspersed with; HC = home cage. *The test for suppression to the tone occurred in an associatively neutral context (context test), whereas the test for suppression to context train and to the light occurred in context train.

ing was then conducted in context train on Days 4-7 so that the cover stimulus would be maximally effective as a signal for the US at the beginning of Phase 2. A flashing light (0.17 sec on/0.17 sec off), 15 sec in duration, served as the cover stimulus. A 1.0-mA 0.5-sec footshock served as the US, which, when presented on cover stimulus-US trials, occurred during the last 0.5 sec of the flashing light. Daily session duration was 60 min. During each session, Group DISTAL:HC was exposed daily to 30 cover stimulus-US pairings interspersed with 8 nonreinforced presentations of the cover stimulus. The nonreinforced presentations of the cover stimulus were designed to match that to be used in Experiment 2. Groups UNS:HC and UNS:CONT— received 30 unsignaled USs per session in order to equal the number of US presentations experienced in context train by Group DISTAL:HC. All USs were pseudorandomly distributed with a mean US-US interval of 106.5 sec. Group ACQ:HC received only exposure to context train.

Following each daily 60-min session in context train, all the animals were placed in context long for an additional 60 min. During this latter 60-min session, Group ACQ:HC received 30 unsignaled 1.0-mA 0.5-sec USs, thereby equaling all groups for the number of daily footshocks. The remaining groups received equivalent exposure to context long, but no footshocks.

Target CS training (Phase 2). Target CS training was conducted in context train on Days 8 and 9. A 15-sec complex tone served as the target CS and a 1.0-mA 0.5-sec footshock served as the US, which occurred during the last 0.5 sec of the tone. Daily session duration was 60 min. All the groups received two target CS-US pairings per session with a 24.75-min intertrial interval, timed from offset of the first target CS-US trial until onset of the second target CS. Group ACQ:HC received only the target CS-US pairings. Groups UNS:HC and UNS:CONT— received these target CS-US pairings intermingled with 30 unsignaled USs. Group DISTAL:HC received the target CS-US pairings intermingled with 30 cover stimulus-US pairings and 8 nonreinforced cover stimulus presentations. The mean US-US interval for unsignaled USs (Groups UNS:HC and UNS:CONT—) and reinforced cover stimuli (Group DISTAL:HC) was 106.5 sec. For all the groups, no programmed event occurred within 2 min of any target CS-US pairing.

Following each target CS training session in context train, all the animals were placed in context long for an additional 60 min. During this latter 60-min session, Group ACQ:HC received 30 unsignaled USs, thereby equaling all groups for the number of daily footshocks. The remaining groups received equivalent exposure to context long, but no footshocks.

Extinction (Phase 3). Extinction treatment was conducted in context train on Days 10-15. Daily session duration was 120 min. Group UNS:CONT— received exposure only to context train (i.e., CONT—). Groups ACQ:HC, UNS:HC, and DISTAL:HC remained in their home cages (i.e., HC). In the present experiments, we did

not control for stimulus specificity of extinction effects; that is, we did not include control groups for which an excitatory nontraining context was extinguished following target CS training. Other work has documented the stimulus specificity of posttraining extinction effects (Miller, Barnett, & Grahame, 1992).

Recovery of baseline behavior. Following extinction treatment, the lick tubes were reinserted and two recovery sessions, designed to reestablish a stable rate of licking, were administered on Days 16 and 17 in context test. During each of these daily 60-min sessions, the animals were placed in context test and no nominal stimulus was presented.

Testing. On Day 18, all the animals were tested in an associatively neutral context (i.e., context test) for suppression of ongoing drinking behavior in the presence of the target CS (i.e., tone). We tested the target CS in an associatively neutral context in these experiments in order to eliminate possible confounds of differential summation between the target CS and the associative value of the context in which the CS was tested. Other work has shown that comparator effects of the sort presented here can also occur when the training and testing contexts are the same (Kaspro, Schachtman, & Miller, 1987). Each animal was placed in context test for 16 min. Following the completion of the first 5 cumulative seconds of licking, the tone was presented for 15 min and latency to complete an additional 5 cumulative seconds of licking in the presence of the tone was recorded. This ensured that all the animals were drinking at CS onset. All test CSs remained on for a fixed duration of 15 min in order to match the duration of exposure to the test CS, thereby avoiding differential treatment that could affect performance on any subsequent test.

On Day 19, the animals were tested for suppression to context train. During this test, lick tubes were available and the subjects were placed in context train for 60 min, during which time no nominal stimulus was presented. Latencies to complete the first 5 cumulative seconds of drinking were recorded.

Finally, on Day 20, the animals were tested in context train for suppression in the presence of the cover stimulus (i.e., light). Testing on Day 20 was procedurally the same as on Day 18, except that the flashing light was presented instead of the tone. Context train, rather than context test, was used for testing the cover stimulus because unpublished data from this laboratory has shown a greater generalization decrement for visual than for auditory CSs when the training and testing contexts differ.

In this and the subsequent experiment, any animal whose test CS score differed from its group mean by more than two standard deviations and any animal that took longer than 60 sec to complete its first 5 cumulative seconds of drinking was excluded from data analysis. In practice, no animal in Experiment 1 and only 1 animal in Experiment 2 met this criterion for exclusion. Prior to statistical analysis, all suppression data were converted to log (base 10) la-

tencies to permit the use of parametric statistics. An alpha level of .05 was selected for all tests of statistical significance.

Results and Discussion

Target CS (Tone) Data

The central outcome of this experiment, observed in the target CS suppression data, was that unsignaled USs that were interspersed among target CS-US pairings attenuated responding to the target CS, and that both post-training extinction of the conditioning context and signaling the intertrial USs reduced this deficit. Figure 1 illustrates the group means for the target CS (tone) data. A one-way analysis of variance (ANOVA), conducted on the Day 18 suppression to the target CS, revealed an effect of treatment [$F(3,44) = 6.15, p < .001$]. The overall error term from this analysis was used to conduct planned comparisons. Three primary findings can be seen in Figure 1. First, Group UNS:HC suppressed less to the target CS than did Group ACQ:HC [$F(1,44) = 13.61, p < .001$]. This demonstrates the detrimental effect that interspersing unsignaled USs among target CS-US pairings had on responding to the target CS, compared with the results from the animals not exposed to unsignaled USs in the training context. Second, Group DISTAL:HC suppressed more to the target CS than did Group UNS:HC [$F(1,44) = 14.34, p < .001$]. Additionally, suppression means ($\pm SE$) for Groups DISTAL:HC and ACQ:HC were virtually identical (1.93 ± 0.16 and 1.91 ± 0.15 , respectively). Thus, recovery of responding to the target CS was observed when the intertrial USs were signaled and not when the intertrial USs remained unsignaled (see Groups DISTAL:HC vs. UNS:HC in Figure 1). More-

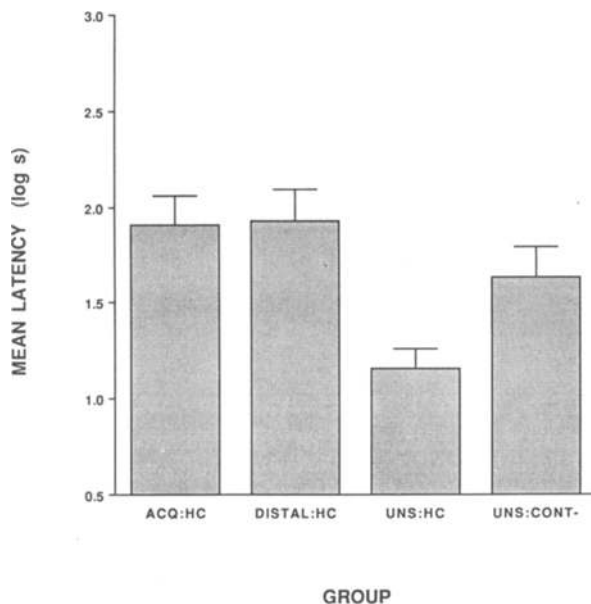


Figure 1. Mean latency to lick for 5 cumulative seconds in the presence of the target CS (tone) as a function of treatment group in Experiment 1. Brackets represent standard errors.

over, signaling the intertrial USs with a cover stimulus appeared to promote complete recovery of responding to the target CS (see Groups DISTAL:HC vs. ACQ:HC in Figure 1).

The present emergence of a deficit in responding to the target CS induced by unsignaled USs and the alleviation of that deficit by signaling the interspersed USs with a cover stimulus is consistent with the observations of other investigators (e.g., Durlach, 1983; Rescorla, 1984). The novel and third primary finding of the present experiment was that Group UNS:CONT- suppressed more to the target CS than did Group UNS:HC [$F(1,44) = 5.34, p < .05$]. Consistent with the predictions of the comparator hypothesis, this result indicates that the deficit in responding to a target CS induced by the provision of unsignaled USs during target CS training can be attenuated by post-training extinction of the conditioning context.

According to the local context version of the comparator hypothesis, the deficit in responding to the target CS induced by unsignaled USs, and the subsequent recovery of responding to the target CS induced by the extinction of context train, were mediated by variations in the excitatory value of the target CS's local context per se. However, the primary manipulations of the present experiment (i.e., the provision of unsignaled USs and the subsequent extinction of context train) most likely influenced the associative value of both local and global context cues, because static apparatus cues probably served as both local and global contexts in this experiment. Therefore, the present data alone provide no ready differentiation between the local and global accounts of contextual control.

Context Train Data

A one-way ANOVA, conducted on the Day 19 suppression to context train, revealed an effect of treatment [$F(3,44) = 8.14, p < .001$]. The overall error term from this analysis was used to conduct planned comparisons.

Figure 2 illustrates the group means for the context train data and reveals that Groups DISTAL:HC and UNS:HC suppressed more to context train than did Group ACQ:HC [$F_s(1,44) \geq 10.99, p_s \leq .001$], suggesting that the provision of intertrial USs in context train enhanced its associative value. It can also be seen that Group UNS:CONT- suppressed less to context train than did Group UNS:HC [$F(1,44) = 13.21, p < .001$], indicating that the context extinction manipulation was effective in attenuating direct control of suppression by the context. It is also noteworthy that levels of suppression to the context were high and nearly identical for Groups DISTAL:HC and UNS:HC (2.21 ± 0.19 and 2.29 ± 0.22 , respectively). This outcome is consistent with the assumption of SET, which proposes that associative acquisition to a conditioning context and a CS trained in that context proceed independently. This observation also poses some challenge for the selective learning view. According to that view, the restorative effect on responding to the target CS by cover signaling occurred because the cover stimulus successfully com-

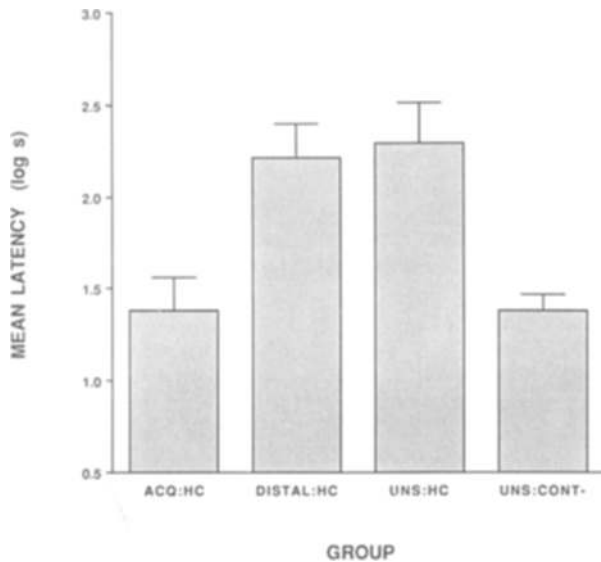


Figure 2. Mean latency to lick for 5 cumulative seconds in the presence of context train as a function of treatment group in Experiment 1. Brackets represent standard errors.

peted with the context for associative strength (e.g., Durlach, 1983; Rescorla, 1984). A reasonable expectation, based on the outcome of such competition, would be lower levels of responding to the context under conditions of signaled relative to unsignaled intertrial USs. Clearly, signaling the otherwise unsignaled USs with a cover stimulus did not appear to protect the context from accruing associative strength in the present experiment. Had such protection occurred, direct levels of suppression to the context would have been lower in Group DISTAL:HC than in Group UNS:HC.

Cover Stimulus (Light) Data

A one-way ANOVA, conducted on the Day 20 suppression to the cover stimulus, revealed an effect of treatment [$F(3,44) = 13.17, p < .001$]. The overall error term from this analysis was used to conduct planned comparisons. The outcome of these analyses is easily summarized. Group DISTAL:HC, the only group that had received pairings of the cover stimulus and the US, suppressed more to the cover stimulus than did the remaining groups [$F_s(1,44) \geq 18.96, p_s < .001$], which did not differ among themselves [$F_s(1,44) \leq 1.35, p_s \geq .25$]. Specifically, mean suppression ($\pm SE$) in the presence of the cover stimulus was 2.19 ($\pm .14$) for Group DISTAL:HC, and was 1.44 ($\pm .11$), 1.30 ($\pm .12$), and 1.24 ($\pm .11$) for Groups UNS:HC, UNS:CONT-, and ACQ:HC, respectively.

EXPERIMENT 2

In Experiment 1, unsignaled USs interspersed during target CS training produced a deficit in responding to the target CS. Furthermore, both signaling the interspersed

USs and posttraining extinction of the target CS's conditioning context attenuated that deficit. On the basis of those findings, however, it remained unclear whether the observed modulation of responding to the target CS was controlled by the associative value of the target CS's local or global context, because the target CS's local context and global context were most likely one and the same (i.e., the apparatus cues). Experiment 2 was designed to directly evaluate the influence of variations in the excitatory value of local context on responding to the target CS. This was accomplished by training a target CS (tone) under conditions in which a pretrained cover stimulus (light) occurred both immediately before and immediately after each target CS-US trial (i.e., light[tone-US]light). Some investigators have argued that the excitatory value of local context modulates conditioned responding to the target CS (e.g., Kaplan & Hearst, 1982; Reilly & Schachtman, 1987; Schachtman & Reilly, 1987). Thus, to the extent that the excitatory value of the local context is the critical modulator of CS performance, responding to the target CS should be deficient when the pretrained cover stimuli occur in the immediate temporal proximity of the target CS training trials, but should not be deficient when the excitatory cover stimuli are more distal to the target CS-US pairings (presumably because the discrete nature of the cover stimulus makes it a better potential modulator of CS performance than diffuse global context cues, when all USs are signaled). Notably, any deficit induced by proximal cover stimuli would be difficult to account for without appealing to the notion of local context, because these conditions differ only with respect to the presence of cover stimuli in the local temporal context of each target CS training trial. These conditions were otherwise comparable regarding the number of target CS-US pairings, cover stimulus-US pairings, and nonreinforced cover stimulus presentations. Moreover, if local context cues per se form the critical basis for comparison to the target CS, then any deficit induced by the presence of proximal cover stimuli should be attenuated following the extinction of the cover stimulus, but not following the extinction of the conditioning context alone.

Method

Subjects

The subjects were 48 male and 48 female, naive Sprague-Dawley rats. Weight ranges were 300-490 g for males and 240-360 g for females. The animals were assigned to one of eight groups ($n = 12$), counterbalanced for sex. They were housed and maintained as in Experiment 1.

Apparatus and Procedure

The apparatus was the same as that used in Experiment 1; the critical aspects of the procedure are summarized in Table 2.

Acclimation. Acclimation to the chambers with lick tubes available was conducted in context train and context test on Days 1-3, as in Experiment 1.

Cover stimulus training (Phase 1). Following acclimation, the lick tubes were removed from all chambers. Cover stimulus training was then conducted in context train on Days 4-7. A flashing light (0.17 sec on/0.17 sec off), 15 sec in duration, served as the

Table 2
Design Summary for Experiment 2

Group	Treatment			
	Phase 1	Phase 2	Phase 3	Test*
	Context Train Days 4-7	Context Train Days 8-9	Days 10-15	Days 18-20
ACQ:HC	-	T+	HC	T, CONT, L
UNS:HC	+	T+ / +	HC	T, CONT, L
DISTAL:HC	L±	T+ / L±	HC	T, CONT, L
DISTAL:CONT-	L±	T+ / L±	CONT-	T, CONT, L
DISTAL:L-	L±	T+ / L±	L-†	T, CONT, L
LOCAL:HC	L±	L(T+)L / L±	HC	T, CONT, L
LOCAL:CONT-	L±	L(T+)L / L±	CONT-	T, CONT, L
LOCAL:L-	L±	L(T+)L / L±	L-†	T, CONT, L

Note—CONT = context train; + = US; - = no US; ± = partial reinforcement; L = light; T = tone; / = interspersed with; HC = home cage. *Because light extinction occurred in context train, both groups that received light extinction also received extinction of context train. †The test for suppression to the tone occurred in an associatively neutral context (context test), whereas the test for suppression to context train and to the light occurred in context train.

cover stimulus, and a 1.0-mA 0.5-sec footshock served as the US, which, when presented, occurred during the last 0.5 sec of the flashing light. Daily session duration was 60 min. Groups DISTAL:HC, DISTAL:CONT-, DISTAL:L-, LOCAL:HC, LOCAL:CONT-, and LOCAL:L- were exposed daily to 30 cover stimulus-US pairings, interspersed with 8 nonreinforced presentations of the cover stimulus. These nonreinforced cover stimulus exposures were intended to prevent the nonreinforced cover stimuli, which were later presented proximally to target CS-US pairings, from being novel during target CS training. Group UNS:HC received 30 unsignaled USs per session in order to match the number of USs experienced by Groups DISTAL and LOCAL. Group ACQ:HC received equivalent exposure to context train, but no USs. The mean US-US interval for unsignaled USs (i.e., Group UNS:HC) and reinforced cover stimuli (i.e., Groups DISTAL and LOCAL) was 106.5 sec.

Following each daily 60-min session in context train, all the animals were placed in context long for an additional 60 min. During this latter 60-min session, Group ACQ:HC received 30 unsignaled USs, thereby equaling all groups for the number of daily footshocks. The remaining groups received equivalent exposure to context long, but no footshocks.

Target CS training (Phase 2). Target CS training was conducted in context train on Days 8 and 9. A 15-sec complex tone served as the target CS and a 1.0-mA 0.5-sec footshock served as the US, which occurred during the last 0.5 sec of the tone. Daily session duration was 60 min. All groups received two target CS-US pairings per session with a 24.75-min intertrial interval, timed from offset of the first target CS-US trial to onset of the second target CS. Group ACQ:HC received only the target CS-US pairings. Group UNS:HC received the target CS-US pairings intermingled with 30 unsignaled USs. Groups DISTAL:HC, DISTAL:CONT-, DISTAL:L-, LOCAL:HC, LOCAL:CONT-, and LOCAL:L- received the target CS-US pairings intermingled with 30 cover stimulus-US pairings and 8 nonreinforced cover stimulus presentations. For Groups LOCAL:HC, LOCAL:CONT-, and LOCAL:L-, 4 of the 8 nonreinforced cover stimuli were presented in pairs, with 1 immediately before and 1 immediately after each of the 2 daily target CS-US pairings. The mean US-US interval for unsignaled USs (i.e., in Group UNS:HC) and USs that reinforced cover stimuli (i.e., in Groups DISTAL and LOCAL) was 106.5 sec. For all groups except the "LOCAL" groups, no events were programmed to occur within 2 min of any target CS-US pairing.

Following each target CS training session in context train, all the animals were placed in context long for an additional 60 min. During this latter 60-min session, Group ACQ:HC received 30 unsignaled USs, thereby equaling all groups for the number of daily footshocks. The remaining groups received equivalent exposure to context long, but no footshocks.

Extinction (Phase 3). Extinction treatment was conducted in context train on Days 10-15. Daily session duration was 120 min. Groups DISTAL:CONT- and LOCAL:CONT- received exposure only to context train. Groups DISTAL:L- and LOCAL:L- received 48 nonreinforced presentations of the cover stimulus (i.e., L-) during each session of the extinction phase. Groups ACQ:HC, UNS:HC, DISTAL:HC, and LOCAL:HC remained in their home cages.

Recovery of baseline behavior. Following extinction treatment, lick tubes were reinserted and two recovery sessions, designed to reestablish a stable rate of licking, were administered on Days 16 and 17 in context test. During each of these daily 60-min sessions, all the animals were placed in context test, where no nominal stimulus was presented.

Testing. Testing on Days 18-20 was identical to that of Experiment 1. On Day 18, all the animals were tested in context test for suppression of ongoing licking behavior in the presence of the target CS (i.e., tone). On Day 19, the animals were tested for suppression to context train, and on Day 20, they were tested in context train for suppression in the presence of the cover stimulus (i.e., light). All other details of Experiment 2 were the same as those specified in Experiment 1.

Results and Discussion

Target CS (Tone) Data

The central finding of Experiment 2 was that proximal cover stimuli resulted in a deficit in responding to the target CS, and that subsequent extinction of the cover stimulus, but not extinction of context train alone, attenuated that deficit. One animal from Group LOCAL:CONT- died before the end of the experiment, and 1 animal from Group DISTAL:HC met the exclusion criterion and was eliminated from the experiment. A one-way ANOVA, conducted on the target CS suppression data from Day 18,

revealed an effect of treatment [$F(7,86) = 24.25, p < .001$]. The overall error term from this analysis was used to conduct planned comparisons.

Figure 3 illustrates the group means for the target CS (tone) data and reveals four primary findings. First, Group UNS:HC suppressed less to the tone than did Group ACQ:HC [$F(1,86) = 35.11, p < .001$]. As in Experiment 1, this indicates the detrimental effect that un signaled USs had on responding to a target CS. Second, Group DISTAL:HC suppressed more to the tone than did Group UNS:HC [$F(1,86) = 50.40, p < .001$]. Thus, also as in Experiment 1, the animals that had the otherwise un signaled USs signaled by a cover stimulus did not appear to show a deficit in responding to the target CS.

Effect of proximal cover stimulus placement. The third primary finding that can be seen in Figure 3 is that Group LOCAL:HC suppressed less to the target CS than did Group DISTAL:HC [$F(1,86) = 47.28, p < .001$]. This shows an impairment in responding to the target CS when two excitatory but nonreinforced cover stimuli immediately surround each target CS-US trial. This impairment is consistent with the view that the excitatory value of local context plays an important role in the modulation of responding to a target CS (e.g., Kaplan & Hearst, 1982; Reilly & Schachtman, 1987; Schachtman & Reilly, 1987). The present observation is difficult to explain without appealing to the notion of local context, because Groups DISTAL:HC and LOCAL:HC received the same number of target CS-US pairings, the same number of cover stimulus-US pairings, and the same number of nonreinforced cover stimulus presentations in the training context.

Inspection of Figure 3 also reveals that Group UNS:HC did not differ from Group LOCAL:HC in suppression to the tone [$F(1,86) < 1$]. This suggests that a similar magnitude of target CS response deficit was induced when the local (and/or global) context was made excitatory by the provision of un signaled USs, and when the local context was made excitatory by the placement of pretrained cover stimuli in the immediate temporal proximity of each target CS trial. It is worth pointing out that both the selective learning view and the comparator hypothesis can account for the observed deficit in responding to the target CS as a result of proximal cover stimulus placement in this experiment. According to the selective learning view, the proximal cover stimuli blocked acquisition to the target CS. According to the comparator hypothesis, the proximal cover stimuli impaired responding but not the acquisition of associative strength to the target CS, presumably by becoming established as the target CS's comparator stimulus. In the sections that follow, evidence will be presented that discriminates between these two views.

Effect of cover stimulus extinction. The fourth primary finding from these data was that Group LOCAL:L- suppressed more to the tone than did Group LOCAL:CONT- [$F(1,86) = 38.92, p < .001$]. This indicates an attenuation of the deficit in responding to the target CS, which arose from proximal placement of ex-

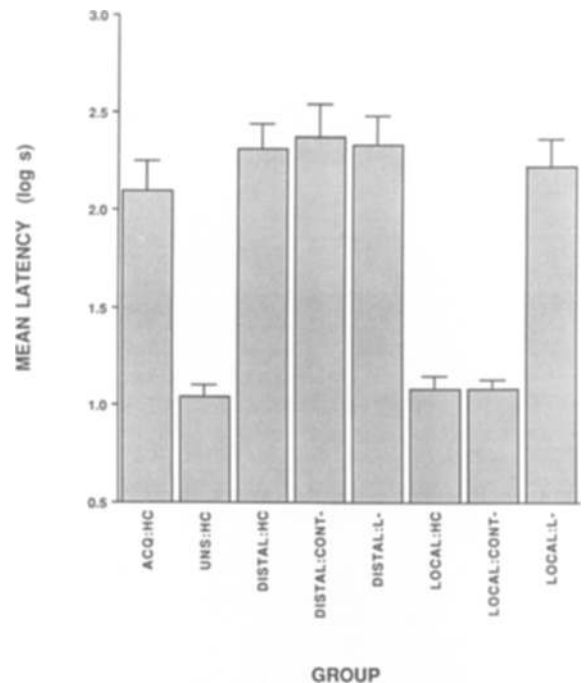


Figure 3. Mean latency to lick for 5 cumulative seconds in the presence of the target CS (tone) as a function of treatment group in Experiment 2. Brackets represent standard errors.

citatory cover stimuli as a result of posttraining extinction of the cover stimulus. Note that this attenuation of the deficit in responding to the target CS was observed under conditions in which the amount of extinction of context train was equal between the comparison groups. (Groups LOCAL:L- and LOCAL:CONT- received equivalent exposure to the apparatus cues because the light was extinguished in context train.) The symmetry in the emergence of response deficits and the subsequent recovery of responding following an extinction treatment, seen in both Experiments 1 and 2, suggests that an explanation of these effects can be captured with a single underlying mechanism. Moreover, because recovery of responding to the target CS was observed in both cases, this mechanism appears to operate on performance, rather than learning. A similar argument has been provided for the related observation that the "overshadowing" response deficit can be alleviated by posttraining extinction of the overshadowing stimulus (e.g., Kaufman & Bolles, 1981; Matzel, Schachtman, & Miller, 1985).

Like the observation in Experiment 1, that recovery of responding to the target CS follows extinction of context train, the present finding, that recovery of responding to the target CS follows cover stimulus extinction, is inconsistent with the selective learning view, which would attribute the deficit in responding to an irreversible acquisition failure. However, the present finding is consistent with the local context version of the comparator hypothesis, which proposes that proximal placement of the cover

stimuli resulted in the establishment of the cover stimulus as a comparator stimulus for the target CS. Because the comparator stimulus-US association was large relative to the target CS-US association as a result of cover stimulus pretraining (as well as the continued cover stimulus training during the target CS training sessions), deficient responding to the target CS was observed. However, posttraining cover extinction degraded the associative value of the local context comparator stimulus, which resulted in a *relative* increase in the associative value of the target CS. Accordingly, the relative increase in the associative value of the target CS promoted recovery of responding to the target CS.

Several observations lead to the suggestion that the associative value of the *proximal* cover stimulus, and not some other aspect of the conditioning situation, controlled responding to the target CS in groups that received proximal cover stimuli and that the recovery of responding to the target CS was a result of cover stimulus extinction. For example, Group LOCAL:CONT- suppressed less to the target CS than did Group DISTAL:CONT- [$F(1,86) = 49.84, p < .001$]. This indicates that, even when putative control by the "global" context was attenuated through posttraining extinction of context train in Group LOCAL:CONT-, a deficit in target CS responding was still observed. Relatedly, suppression means to the target CS for Groups LOCAL:HC and LOCAL:CONT- were 1.08 and 1.08 log sec, respectively. Thus, the deficit induced by the proximal cover stimuli was largely independent of the associative value of the global context. However, the possible contribution of floor effects in the failure to see a recovery of responding to the target CS in Group LOCAL:HC cannot be ruled out.

Responding to the target CS was similar for the groups that did not receive the cover stimuli proximal to the target CS; suppression means for Groups DISTAL:HC and DISTAL:CONT- were 2.31 and 2.37 log sec, respectively. For these latter DISTAL groups, which did not receive the cover stimuli proximal to the target CS training trials, posttraining cover stimulus extinction did not influence responding to the target CS. Such an observation is not surprising, given that responding to the target CS in these groups was high and appeared asymptotic. (Mean suppression for Group DISTAL:CONT- was 2.37 log sec, and for Group DISTAL:L- was 2.33 log sec.) Collectively, these observations suggest that the associative value of the proximal cover stimulus per se was controlling responding to the target CS. The detrimental effect of the proximal cover stimuli was the same with or without extinction of the global context, and when the cover stimulus was not proximal to the target CS training trials, neither context extinction nor cover stimulus extinction appeared to influence responding to the target CS.

Context Train Data

A one-way ANOVA, conducted on the context train suppression data of Day 19, revealed an effect of treatment [$F(7,86) = 20.31, p < .001$]. The overall error term from this analysis was used to conduct planned comparisons.

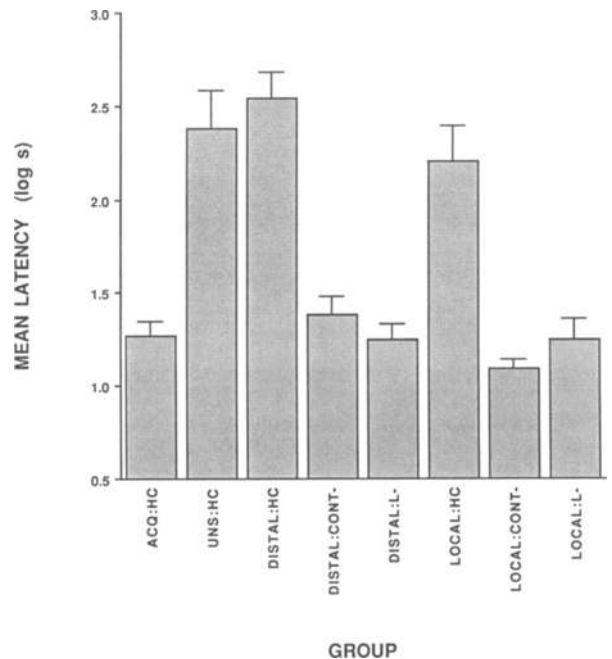


Figure 4. Mean latency to lick for 5 cumulative seconds in the presence of context train as a function of treatment group in Experiment 2. Brackets represent standard errors.

Figure 4 illustrates group means for the context train data. As was found in Experiment 1, Group UNS:HC suppressed more to the context than did Group ACQ:HC [$F(1,86) = 36.06, p < .001$], suggesting that the effect of the unsignaled USs was to enhance the associative value of context train. It can also be seen in Figure 4 that Group UNS:HC did not differ from Group DISTAL:HC in suppression to context train [$F(1,86) < 1$]. This observation parallels that from Experiment 1 by suggesting that signaling the intertrial USs with a cover stimulus did not affect the associative value of context train. However, posttraining extinction of context train did appear to influence its associative status. Specifically, Groups DISTAL:CONT- and LOCAL:CONT- suppressed less to context train than did Groups DISTAL:HC and LOCAL:HC, respectively [$F(1,86) \geq 34.50, ps < .001$]. Figure 4 also reveals relatively low levels of suppression to context train for Groups DISTAL:L- and LOCAL:L-, which is not surprising because these groups received extinction of the cover stimulus in context train (and therefore also received extinction of context train). Finally, Groups DISTAL:HC and LOCAL:HC did not differ in suppression to context train [$F(1,86) = 3.38, p > .05$], nor did Groups DISTAL:CONT- and LOCAL:CONT- differ [$F(1,86) = 2.36, p > .10$]. This latter pattern of responding to context train suggests that the deficit in responding to the target CS, evident when the cover stimuli were proximal to target CS trials (see Groups LOCAL:HC vs. DISTAL:HC and LOCAL:CONT- vs. DISTAL:CONT- in Figure 3), was not controlled by the excitatory value of the "global" training context.

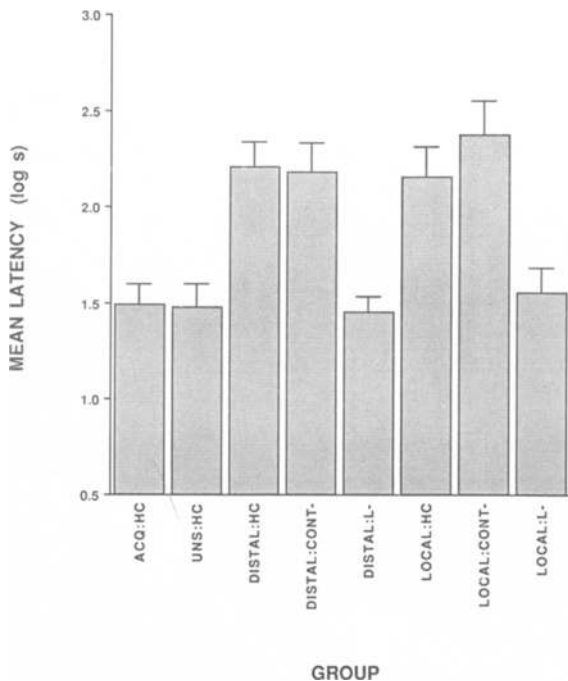


Figure 5. Mean latency to lick for 5 cumulative seconds in the presence of the cover stimulus (light) as a function of treatment group in Experiment 2. Brackets represent standard errors.

Cover Stimulus (Light) Data

A one-way ANOVA, conducted on the cover stimulus suppression data of Day 20, revealed an effect of treatment [$F(7,86) = 8.25, p < .001$]. The overall error term from this analysis was used to conduct planned comparisons.

Figure 5 illustrates group means for the cover stimulus (light) data. Except for Groups LOCAL:L- and DISTAL:L-, it can be seen that the animals exposed to pairings of the cover stimulus and the US (i.e., Groups LOCAL:HC, LOCAL:CONT-, DISTAL:HC, and DISTAL:CONT-) suppressed more to the cover stimulus than did the animals not exposed to pairings of the cover stimulus and the US (i.e., Groups ACQ:HC and UNS:HC, for which testing was the first time that the flashing light was encountered) [$F_s(1,86) \geq 11.51, p_s < .001$]. Additionally, Groups DISTAL:L- and LOCAL:L- suppressed less to the cover stimulus than did Groups DISTAL:CONT- and LOCAL:CONT-, respectively [$F_s(1,86) \geq 14.08, p_s < .001$], indicating that extinction of the cover stimulus was effective in attenuating direct behavioral control by the cover stimulus. Groups DISTAL:HC and DISTAL:CONT- did not differ from Groups LOCAL:HC and LOCAL:CONT- in suppression to the cover stimulus, respectively [$F_s(1,86) < 1$]. This observation suggests that the differences in responding to the target CS in Groups DISTAL:HC versus LOCAL:HC and in Groups DISTAL:CONT- versus LOCAL:CONT-, seen in Figure 3, were not due to differences in the associative sta-

tus of the cover stimulus. Thus, the critical variable controlling the deficit in responding to the target CS in the LOCAL conditions appears to be the temporal placement of the nonreinforced cover stimulus presentations with respect to the target CS-US trials. Finally, Groups DISTAL:HC and DISTAL:CONT- did not differ, and Groups LOCAL:HC and LOCAL:CONT- did not differ [$F_s(1,86) \leq 1.22, p_s > .25$], indicating that context extinction did not influence the response potential of the cover stimulus (as context extinction had influenced the response potential of the target CS in Experiment 1). This outcome is not surprising, given that responding to the cover stimulus in these groups was high and appeared asymptotic, thus suggesting that ceiling effects may have masked any potential modulation of responding to the cover stimulus by the associative value of context train.

GENERAL DISCUSSION

The findings of the present experiments extend the basis for our understanding of how the excitatory value of a CS's local context cues modulates conditioned responding to the CS. In Experiment 1, a target CS was trained under conditions in which unsignaled USs were interspersed with target CS-US trials. Consistent with a variety of other behavioral observations under similar training conditions (e.g., Ayres et al., 1975; Durlach, 1983; Rescorla, 1968), a deficit in responding to the target CS was observed. Experiment 1 further revealed that this deficit in responding to a target CS could be attenuated in two different ways. First, the deficit was attenuated when the otherwise unsignaled USs were signaled with a cover stimulus, a finding that is also consistent with the observations of others (e.g., Durlach, 1983; Rescorla, 1984). Second, the deficit in responding to the target CS was attenuated by posttraining extinction of the conditioning context, a novel finding that was uniquely predicted by the comparator hypothesis. This latter finding serves to emphasize the importance of relative, rather than absolute, associative strength of a CS in the expression of acquired information about the CS. In this respect, such an observation is also consistent with the assumptions of SET (Gibbon & Balsam, 1981).

The primary goal of these experiments, however, was to evaluate the application of a local context view (e.g., Reilly & Schachtman, 1987; Schachtman & Reilly, 1987) to the comparator hypothesis. According to this formulation, the critical comparator term for a target CS arises from the US expectancy evoked by cues in the local temporal context of the target CS training trial, rather than from the US expectancy evoked by the general background of the conditioning situation. Thus, treatments that influence the excitatory value of the training context will modulate responding to the CS only to the extent that those treatments influence the excitatory value of *local* context cues. Although the observations of Experiment 1 were consistent with this account, they were not uniquely supportive of it. In Experiment 1, it remained unclear

whether the unsignaled USs and subsequent context extinction influenced responding to the target CS by modulating US expectancy that was based on the local context, the global context, or both. This uncertainty arose because the stimulus conditions prevailing immediately before and after each target CS-US trial were probably not discriminated from the stimulus conditions prevailing during the remainder of the intertrial intervals. However, the observations of Experiment 2 are difficult to explain without appealing to the idea that local context cues *per se* serve as the comparator stimulus for the target CS. Specifically, a deficit in responding to the target CS was observed under conditions in which a pretrained cover stimulus occurred both immediately before and immediately after each target CS-US trial (e.g., see Group LOCAL:HC in Figure 3). This deficit was not observed under identical training conditions, except for the presence of cover stimuli in the immediate temporal proximity of each target CS-US trial (see Group DISTAL:HC in Figure 3). Moreover, in the LOCAL conditions, recovery of responding to the target CS was observed following extinction of the cover stimulus, but not following extinction of the training context alone (see Groups LOCAL:L- vs. LOCAL:CONT- in Figure 3). Collectively, these observations suggest that the local context cues *per se* (i.e., the cover stimuli temporally proximal to the target CS-US trials) became established as the target CS's comparator stimulus. Thus, the comparator hypothesis, equipped with the local context corollary of Schachtman and Reilly (1987; Reilly & Schachtman, 1987), provides a plausible account of how local context influences responding to a target CS.

In both of the present experiments, responding to the target CS, responding to the cover stimulus, and responding to the context were directly assessed. This is important, because these assessments permit within-experiment evaluations of what effect signaling the otherwise unsignaled USs with the cover stimulus had on the presumed associative strength of the context, in addition to what effect signaling the otherwise unsignaled USs had on responding to the target CS. Such an evaluation is useful, because considerable debate persists concerning what mechanisms underlie the restorative effect of signaling intertrial USs on responding to a target CS, and relatedly, what effect such signaling has on the associative value of contextual cues.

Some investigators have argued that the restorative effect of signaling intertrial USs occurs because the cover stimulus effectively competes with the context for associative strength made available by the US (e.g., Durlach, 1983; Rescorla, 1984). According to this argument, when the intertrial USs are signaled with a cover stimulus, the context does not block associative acquisition to the target CS because it has not become sufficiently excitatory to do so. Other investigators have suggested that signaling interspersed USs converts the conditions prevailing during the intertrial interval (i.e., apparatus cues alone) into a signal for US absence because, under conditions

of signaling by the cover stimulus, USs never occur in the presence of the apparatus cues alone (e.g., Goddard & Jenkins, 1987). In this view, conversion of the intertrial interval into a signal for US absence is assumed to induce a contrast between the US probability during the intertrial interval and the US probability during the target CS. This contrast is presumed to be the critical feature that permits responding to the target CS when the intertrial USs are signaled by a cover stimulus.

Both of these views seem to predict less direct responding to contextual cues under conditions of signaled intertrial USs than under conditions of unsignaled intertrial USs. According to the cover/context associative competition account, when the intertrial USs are signaled, the context should be only weakly conditioned because it did not adequately compete with the cover stimulus for the associative strength of the interspersed USs. The contrast account proposes that contextual cues present during the intertrial interval signal nonreinforcement under conditions of signaled USs, but signal reinforcement under conditions of unsignaled USs. Thus, according to both accounts, contextual cues should be less excitatory when the intertrial USs are signaled than when the intertrial USs are unsignaled.

The available evidence on whether signaling intertrial USs influences the associative value of the context, measured by direct responding to contextual cues, is unpleasantly mixed. Several reports, which have used (1) general activity with pigeons (Rescorla, Durlach, & Grau, 1985) or ring doves (Balsam, 1984), (2) conditioned freezing (Williams, Frame, & LoLordo, 1992), or (3) suppression of licking behavior (the present report) with rats as direct measures of contextual conditioning have failed to reveal differences in responding to contextual cues between conditions of signaled and unsignaled reinforcement. The paradox created by these findings is that signaling intertrial USs attenuates the deficit in responding to the target CS induced by unsignaled USs without influencing the apparent associative value of the context, despite differences in the associative value of the context being presumed to underlie the effect of signaling (cf. Rescorla et al., 1985). It is of course possible that these direct behavioral measures are not sensitive to differences in the associative value of contextual cues in the signaled and unsignaled conditions. However, the convergent outcome, that there is no difference in direct responding to contextual cues with the wide variety of species and response measures tested thus far, suggests that a simple "lack of sensitivity" account is inadequate.

The above examples of equivalent responding to contextual cues under conditions of signaled and unsignaled USs are entirely consistent with the assumption of SET—that associative acquisition to a target CS and the context in which it is trained are independent (Gibbon & Balsam, 1981). However, the original formulation of SET cannot account for the restored responding to a target CS when interspersed USs are signaled by a cover stimulus, because whether those USs are signaled or unsignaled should

not influence the C/T ratio. In order to deal with this problem, Cooper, Aronson, Balsam, and Gibbon (1990; Cooper, 1991) have proposed an intriguing modification of Gibbon and Balsam's SET, called the *deletion* comparator hypothesis. According to the deletion comparator hypothesis, cover stimuli and their accompanying USs are "deleted" from the effective comparator term. The "removal" of cover stimuli and their USs has been shown under some conditions to yield a C_D/T ratio (where C_D is the modified "deletion cycle") for the target CS in excess of the threshold value for responding, whereas in the original formulation of SET, the C/T ratio would have been near or below threshold. Thus, the deletion comparator hypothesis can account for the restorative effect of signaling intertrial USs on responding to a target CS. The deletion comparator hypothesis might also be capable of explaining the apparent equivalence in the associative strength of contextual cues under conditions of signaled versus unsignaled intertrial USs by sustaining the assumption of SET, that associative acquisition to CSs and contextual cues occurs independently. The possibility here is that the response potential of any given CS may be controlled by a comparison of the associative strength of that CS to the associative strength of its associated background cues with alternate signals deleted, but that such a deletion does not impact the ability of the background to directly control behavior. Thus, the deletion of cover stimulus-US trials from the effective comparator term for the target CS might not impact the ability of contextual cues presented in isolation at test to reactivate associations with the US that became established as a consequence of USs presented in the presence of those contextual cues on reinforced cover stimulus trials.¹

Other reports, however, using (1) general activity with pigeons (Grau & Rescorla, 1984), (2) suppression of baseline barpress behavior (Baker, Mercier, Gable, & Baker, 1981), or (3) place-preference tests with rats (Fanselow, 1980; Odling-Smee, 1975, 1978; see also Marlin, 1981) as direct measures of contextual conditioning have revealed differences in direct responding to contextual cues as a function of whether or not the USs were signaled. Although careful attention to differences in procedural detail may reconcile some of these differences in experimental outcomes (e.g., Grau & Rescorla, 1984), it is clear that no comprehensive resolution is presently available.

Nonetheless, the outcomes of the present experiments are consonant with the suggestion of others (e.g., Reilly & Schachtman, 1987; Schachtman & Reilly, 1987), in that comparator views should reconsider exactly what aspects of the conditioning situation comprise the basis of comparison to the target CS. The recent reports by Cooper et al. (1990) and Cooper (1991) indicate that such a reformulation is well underway, and suggest that an extreme molar analysis of contextual control is inadequate. Continued progress in the development of comparator theories of Pavlovian conditioning will most likely require a movement away from viewing contextual control over responding to the CS as a simple dictate of an associative value

of the training context characterized by an average inter-trial interval.

REFERENCES

- AYRES, J. J. B., BENEDICT, J. O., & WITCHER, E. S. (1975). Systematic manipulation of individual events in a truly random control in rats. *Journal of Comparative & Physiological Psychology*, *88*, 97-103.
- BAKER, A. G., MERCIER, P., GABLE, J., & BAKER, P. A. (1981). Contextual conditioning and the US preexposure effect in conditioned fear. *Journal of Experimental Psychology: Animal Behavior Processes*, *7*, 109-128.
- BALSAM, P. D. (1984). Bringing the background to the foreground: The role of contextual cues in autoshaping. In M. Commons, R. Herrnstein, & A. Wagner (Eds.), *Quantitative analyses of behavior: Vol. 3. Acquisition* (pp. 145-171). New York: Ballinger.
- CHAMPION, R. A. (1961). Supplementary report: Interpolated UCS trials in GSR conditioning. *Journal of Experimental Psychology*, *62*, 206-207.
- COOPER, L. D. (1991). Temporal factors in classical conditioning. *Learning & Motivation*, *22*, 129-152.
- COOPER, L. D., ARONSON, L., BALSAM, P. D., & GIBBON, J. (1990). Duration of signals for intertrial reinforcement and nonreinforcement in random control procedures. *Journal of Experimental Psychology: Animal Behavior Processes*, *16*, 14-26.
- DURLACH, P. J. (1983). Effect of signaling intertrial unconditioned stimuli in autoshaping. *Journal of Experimental Psychology: Animal Behavior Processes*, *9*, 374-389.
- DURLACH, P. J. (1986). Explicitly unpaired procedure as a response elimination technique in autoshaping. *Journal of Experimental Psychology: Animal Behavior Processes*, *12*, 172-185.
- DURLACH, P. J. (1989). Roles for unconditioned stimulus absence in the sensitivity of autoshaping to contingency. *Journal of Experimental Psychology: Animal Behavior Processes*, *15*, 202-211.
- FANSELOW, M. S. (1980). Signaled shock-free periods and preference for signaled shock. *Journal of Experimental Psychology: Animal Behavior Processes*, *6*, 65-80.
- GAMZU, E. R., & WILLIAMS, D. R. (1973). Associative factors underlying the pigeon's key pecking in auto-shaping procedures. *Journal of the Experimental Analysis of Behavior*, *19*, 225-232.
- GIBBON, J. (1977). Scalar expectancy theory and Weber's law in animal timing. *Psychological Review*, *84*, 279-325.
- GIBBON, J., & BALSAM, P. D. (1981). Spreading association in time. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), *Autoshaping and conditioning theory* (pp. 219-253). New York: Academic Press.
- GODDARD, M. J., & JENKINS, H. M. (1987). Effect of signaling extra unconditioned stimuli on autoshaping. *Animal Learning & Behavior*, *15*, 40-46.
- GRAU, J. W., & RESCORLA, R. A. (1984). Role of context in autoshaping. *Journal of Experimental Psychology: Animal Behavior Processes*, *10*, 324-332.
- JENKINS, H. M., BARNES, R. A., & BARRERA, F. J. (1981). Why autoshaping depends on trial spacing. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), *Autoshaping and conditioning theory* (pp. 255-284). New York: Academic Press.
- KAPLAN, P. S., & HEARST, E. (1982). Bridging temporal gaps between CS and US autoshaping: Insertion of other stimuli before, during, and after CS. *Journal of Experimental Psychology: Animal Behavior Processes*, *8*, 187-203.
- KASPROW, W. J., SCHACHTMAN, T. R., & MILLER, R. R. (1987). The comparator hypothesis of conditioned response generation: Manifest conditioned excitation and inhibition as a function of the relative excitatory strengths of CS and conditioning context at the time of testing. *Journal of Experimental Psychology: Animal Behavior Processes*, *13*, 395-406.
- KAUFMAN, M. A., & BOLLES, R. C. (1981). A nonassociative aspect of overshadowing. *Bulletin of the Psychonomic Society*, *18*, 318-320.
- MARLIN, N. A. (1981). Contextual associations in trace conditioning. *Animal Learning & Behavior*, *9*, 519-523.
- MATZEL, L. D., BROWN, A. M., & MILLER, R. R. (1987). Associative

- effects of US preexposure: Retarded conditioned responding mediated by an excitatory training context. *Journal of Experimental Psychology: Animal Behavior Processes*, **13**, 65-72.
- MATZEL, L. D., SCHACHTMAN, T. R., & MILLER, R. R. (1985). Recovery of an overshadowed association achieved by extinction of the overshadowing stimulus. *Learning & Motivation*, **16**, 398-412.
- MILLER, R. R., BARNET, R. C., & GRAHAME, N. J. (1992). Responding to a conditioned stimulus depends on the current associative status of other cues that were present during training of that specific stimulus. *Journal of Experimental Psychology: Animal Behavior Processes*, **18**, 251-264.
- MILLER, R. R., & MATZEL, L. D. (1988). The comparator hypothesis: A response rule for the expression of associations. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 1-46). Orlando: Academic Press.
- MILLER, R. R., & SCHACHTMAN, T. R. (1985). Conditioning context as an associative baseline: Implications for response generation and the nature of conditioned inhibition. In R. R. Miller & N. E. Spear (Eds.), *Information processing in animals: Conditioned inhibition* (pp. 51-88). Hillsdale, NJ: Erlbaum.
- ODLING-SMEE, F. J. (1975). The role of background stimuli during Pavlovian conditioning. *Quarterly Journal of Experimental Psychology*, **27**, 201-209.
- ODLING-SMEE, F. J. (1978). The overshadowing of background stimuli by an informative CS in aversive Pavlovian conditioning with rats. *Animal Learning & Behavior*, **6**, 43-51.
- REILLY, S., & SCHACHTMAN, T. R. (1987). The effects of ITI fillers in autoshaping. *Learning & Motivation*, **18**, 202-219.
- RESCORLA, R. A. (1968). Probability of shock in the presence and absence of the CS in fear conditioning. *Journal of Comparative & Physiological Psychology*, **66**, 1-5.
- RESCORLA, R. A. (1972). Informational variables in Pavlovian conditioning. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 6, pp. 1-46). New York: Academic Press.
- RESCORLA, R. A. (1984). Signaling intertrial shocks attenuates their negative effect on conditioned suppression. *Bulletin of the Psychonomic Society*, **22**, 225-228.
- RESCORLA, R. A., DURLACH, P. J., & GRAU, J. W. (1985). Contextual conditioning in Pavlovian conditioning. In P. D. Balsam & A. Tomie (Eds.), *Context and learning* (pp. 23-56). Hillsdale, NJ: Erlbaum.
- RESCORLA, R. A., & WAGNER, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and non-reinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II: Current research and theory* (pp. 64-99). New York: Appleton-Century-Crofts.
- SCHACHTMAN, T. R., & REILLY, S. (1987). The role of local context in autoshaping. *Learning & Motivation*, **18**, 343-355.
- TOMIE, A. (1981). Effect of unpredictable food on the subsequent acquisition of autoshaping: Analysis of the context blocking hypothesis. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), *Autoshaping and conditioning theory* (pp. 181-215). New York: Academic Press.
- WILLIAMS, D. A., FRAME, K. A., & LOLORDO, V. M. (1992). Discrete signals for the unconditioned stimulus fail to overshadow contextual or temporal conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, **18**, 41-55.

NOTE

1. The ideas expressed here concerning the ability of the deletion comparator hypothesis to account for equivalent responding to contextual cues under conditions of signaled and unsignaled USs are based on a December 20, 1991 discussion with Peter Balsam.

(Manuscript received January 3, 1992;
revision accepted for publication July 13, 1992.)

Notice

Nominations for the Editorship of *Animal Learning & Behavior*

Nominations are solicited for the editorship of *Animal Learning & Behavior*. The term of the present editor, Vincent M. LoLordo, expires at the end of 1994. The new editor will begin an official 4-year term January 1, 1995. It is expected that the Publications Committee of the Psychonomic Society will make the appointment by November 1993.

Nominations must be submitted by July 1, 1993.

Nominations (including self-nominations) should be sent to:

Michael Domjan
Department of Psychology
University of Texas
Austin, TX 78712