

**Effects of Nonreinforced Preexposure
to the Context on Autoshaping in Rats:
Methodological Implications for Demonstrations of Latent Inhibition**

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Experiments designed to study latent inhibition typically use as a control condition a group of animals preexposed to the training context, but not to the conditioned stimulus (i.e., the context control). Experiments using the rat autoshaping preparation demonstrate that nonreinforced preexposure to the context facilitates subsequent conditioning to a discrete stimulus, particularly with large reinforcers (Experiment 1) and dramatically enhances performance under the unfavorable conditions posed by massed training (Experiment 2). Furthermore, it is nonreinforced preexposure to the training context, and not to a nontraining context, that enhances autoshaping performance (Experiment 3). The facilitatory effect of nonreinforced preexposure to the training context questions the exclusive use of the context control in latent inhibition experiments and suggests that findings based on such comparisons need to be reevaluated.

Pavlovian conditioning resulting from the pairing of a conditioned stimulus (CS) and an unconditioned stimulus (US) can be interfered with by nonreinforced preexposure to the CS, a phenomenon called latent inhibition or the CS-preexposure effect. The CS-preexposure effect has been reported in numerous conditioning preparations (Lubow, 1989). In a typical demonstration, Tranberg and Rilling (1978) pretrained pigeons to eat from the food tray and subsequently assigned them to two conditions. In one condition, pigeons received 50 nonreinforced presentations of a green key light in each of 10 sessions, followed by four 50-trial sessions of autoshaping in which the green key light (the CS) was paired with food (the US). Acquisition after CS preexposure was retarded relative to the performance of a group preexposed to the context but not to the CS (i.e., the context-control group).

There are two problems with this typical demonstration of latent inhibition: the exclusive use of a context control and the food pretraining procedure. Consider, first, Tranberg and Rilling's (1978) exclusive use of the context control to assess the presence of the CS-preexposure effect. A survey of publications in 17 journals during the period 1996-2001, using PubMed and PsycInfo, and "latent inhibition" and "CS preexposure" as the key words supported the assertion that the context control is the most popular control procedure in the literature on the CS-preexposure effect (see Table 1; for recent examples, see Coutureau et al., 2002; Reed & Tsakanikos, 2002). Despite its popularity, however, the context control introduces an important confound that has hitherto received little consideration. Assuming that the nonreinforced preexposure of a stimulus interferes with the subsequent ability of that stimulus to control behavior via conditioning, then the nonreinforced preexposure of the contextual stimuli should be expected to produce the

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same effect (i.e., interference with subsequent contextual conditioning). This context-preexposure effect is predicated on the assumption that discrete CSs and static contextual stimuli obey similar conditioning principles (see Balsam & Tomie, 1985).

Table 1
A Survey of Control Conditions in CS-Preexposure Experiments.

Control Condition	Frequency (%)
Context Control Only	49 (71.0)
Context Control plus Original Acquisition	3 (4.3)
Nontarget CS	3 (4.3)
Within-Subject Design	2 (2.9)
Water Control (Taste Aversion)	12 (17.4)
Total	69

Note. The articles surveyed were published in the following journals: *Animal Learning and Behavior*, *Behavioral Neuroscience*, *Behavioural Brain Research*, *Brain Research*, *Brain Research Bulletin*, *Experimental Brain Research*, *Journal of Experimental Psychology: Animal Behavior Processes*, *Journal of Neuroscience*, *Learning and Memory*, *Learning and Motivation*, *Neurobiology of Learning and Memory*, *Neuroscience*, *Pharmacology Biochemistry and Behavior*, *Physiology and Behavior*, *Psychobiology*, *Psychopharmacology*, and *Quarterly Journal of Experimental Psychology*. See text for further details.

Although the context-preexposure effect has attracted less attention than the conventional CS-preexposure effect, available evidence suggests that preexposure to the conditioning context in the absence of both the CS and the US facilitates the rate of acquisition to the CS in a subsequent conditioning phase, relative to animals that received no context preexposure (Balaz et al., 1982; Grant & Young, 1971; Hinderliter & Misanin, 1993). Extensive preexposure to the context before each training session can also facilitate subsequent conditioning of the CS (Burns & Domjan, 2001; Papini, Linwick, & Overmier, 1987). Most accounts of latent inhibition predict that nonreinforced preexposure to the context should lead to a loss of associability by contextual cues and hence enhance acquisition to the CS (e.g., Lubow, 1989; Pearce & Hall, 1980). Conditioning of the CS following context preexposure is facilitated because the CS is presented against a background of stimuli that have lost a considerable amount of associability. In the experimental group, in contrast, nonreinforced presentations of the CS during the preexposure phase may disrupt this context-preexposure effect. Evidence consistent with this proposition is found in experiments in which two discrete CSs are administered during preexposure. Latent inhibition to a target CS is attenuated when a second CS is presented immediately before, during, or after the target CS during the CS preexposure phase (Batson & Best, 1982; Lubow, Schnur, & Rifkin, 1976; Mackintosh, 1973; Reed, 1995; Rudy, Krauter, & Gaffuri, 1976). The second CS seems

to eliminate any decrement otherwise induced by nonreinforced presentations of the target CS. Because contextual cues precede, follow, and are simultaneously presented with the CS, it seems plausible that a similar disruption of latent inhibition may apply to the context. Greater disruption of contextual latent inhibition in the experimental group than in the context control group would tend to overestimate the size of any CS-preexposure effect based on such a comparison.

One way to test this hypothesis is to include two control groups. One is the typical context control that equates experience with the context relative to the experimental group. This control is needed to demonstrate that it is preexposure to the CS, and not to the context, that retards acquisition to the CS in the subsequent phase. The other is an original acquisition control (a group receiving no preexposure to the CS or context) that provides a measure of acquisition that, unlike in the context control, is uninfluenced by context preexposure. The CS-preexposure effect can be more conclusively demonstrated when animals receiving nonreinforced CS preexposure acquire conditioning at a significantly slower rate than that exhibited by both the context and original-acquisition controls. Notice, however, that neither of these control conditions would be enough on their own to demonstrate the CS-preexposure effect. The context control confounds retardation of acquisition to the CS with possible facilitation induced by context preexposure, whereas the original-acquisition control confounds preexposure to the CS with preexposure to the context.

Consider, second, the food pretraining procedure, a problem that arises in appetitive demonstrations of the CS-preexposure effect such as that reported by Tranberg and Rilling (1978). An initial phase of pretraining was designed to shape the pigeon's food-procuring responses, including approaching the food hopper, pecking at the grain, and consuming the food. These responses are required during subsequent autoshaping training, when the green key light (the CS) was paired with food (the US). Because the animal has to procure the food by itself, feeding responses must be shaped in advance so that the US can have the intended reinforcing effect. Typically, magazine pretraining involves unsignaled food presentations in the same context in which both CS preexposure and CS-US conditioning would later take place (e.g., Mackintosh, 1973; Reed, Anderson, & Foster, 1999; Reilly, 1987). This introduces at least two problems. The first problem is the potential for the CS to acquire inhibitory conditioning. The sequence of training phases is equivalent to Pavlov's A+/AB- conditioned inhibition paradigm, except that the context replaces the excitatory CS (labeled "A") and the two types of trial are presented sequentially, rather than concurrently. There is evidence suggesting that serial A+ → AB- training can result in the development of inhibitory conditioning to B (Rescorla, 1979). The second problem arises because retardation of CS conditioning could potentially follow from contextual blocking, which occurs when contextual conditioning retards subsequent CS conditioning (Tomie, 1976). Obviously, nonreinforced exposure to the context after magazine pretraining and during the preexposure phase would tend to extinguish the context's value. However, if extinction is incomplete or if the initial USs delivered during acquisition training cause a rapid reacquisition of the context-US association, then CS acquisition could be retarded purely because of contextual blocking of the CS-US association.

Despite the extensive literature dealing with the CS-preexposure effect, the

two concerns raised previously (namely, the exclusive use of the context control and food pretraining) have not been adequately addressed. The latter problem is solved in the present experiments by using a training preparation (autoshaping in rats) that does not require any food pretraining. In all the autoshaping experiments reported in the present article, rats received preexposure to the CS prior to any delivery of food. This feature eliminates alternative accounts of retardation of acquisition based on inhibitory conditioning and contextual blocking that obscure the interpretation of most latent inhibition results from food-reinforcement preparations. The problem of the exclusive use of a context control is addressed in three experiments designed to evaluate the extent to which nonreinforced preexposure to the context enhanced subsequent autoshaping. Failure to address this methodological concern casts doubts on the empirical status of available demonstrations of the CS-preexposure effect, as well as on theoretical efforts to uncover its underlying mechanisms.

Experiment 1

Experiment 1 sought to examine the CS preexposure effect using both a context control group and an original acquisition control group. Rats in the context control group were preexposed to the context in the absence of both CS and US, and during an amount of time equivalent to that of the rats preexposed to the CS. In contrast, rats in the original acquisition group received no preexposure to the context, CS, or US. There are reasons to expect that the degree to which a group receiving nonreinforced preexposure to the CS differs from a context control condition might vary as a function of US magnitude. Although using a different procedure from that of the present experiments, De La Casa and Lubow (2000) reported an experiment using taste aversion with rats that yielded results consistent with this expectation. In one experiment, rats received nonreinforced preexposure to saccharin (the CS), followed by one pairing of the CS with a lithium chloride injection (the US), and ending in a series of tests with the CS alone administered 21 days later. The two factors of interest in this study were the presence or absence of preexposure experience (nonpreexposed rats remained in the training context during preexposure trials) and the magnitude of the US (a 5:1 difference in the doses of lithium chloride). One of the main findings of this study was greater suppression of drinking in the context control than in the preexposed rats in the condition involving a high dose US, but a nonsignificant effect in the groups trained with the low dose. For our purposes, what is interesting about these results is that the apparent enhancement of latent inhibition by a high-intensity US was entirely attributable to an effect of US intensity on the performance of the control group (see Figure 2 in De La Casa & Lubow, 2000). An alternative interpretation of this effect would suggest that rats preexposed to the context and then given a CS-US pairing with a high magnitude US showed enhanced CS acquisition.

Experiment 1 was designed to replicate and extend the results reported by De La Casa and Lubow (2000). This experiment tested the effects of US magnitude (also a 5:1 ratio, but of food pellets) on the CS-preexposure effect by comparing the performance of the group preexposed to the CS with that of a context control (as done by De La Casa & Lubow, 2000), and also with that of an original acquisition control. The original acquisition control permitted an evaluation of the

effect of nonreinforced preexposure to the training context. Previous research demonstrated that the rat autoshaping preparation is sensitive to US magnitude (Thomas et al., 1998). Furthermore, it seems plausible that studies of latent inhibition would tend to use medium- or high-intensity USs to optimize training conditions. If a sizable context-preexposure effect were obtained with large USs, then the popular approach of interpreting the CS-preexposure effect exclusively on the basis of a comparison against the context control would be called into question.

Method

Subjects. The subjects were 72 male, experimentally naïve Wistar rats, approximately 90 days old at the start of the experiment. Rats were obtained from the TCU breeding colony. Rats were maintained at 85% of their ad libitum weights throughout the experiment by limiting their daily food allowance. Each animal was housed in an individual home cage with ad libitum water. The housing vivarium was subject to a 12:12 h light:dark cycle (light on at 07:00 h). Training sessions were administered between 12:00 and 17:00 h.

Apparatus. Six standard operant chambers (MED Associates) were used. Four of them measured 20.1 cm wide, 28 cm long, and 20.5 cm high. The floor of the boxes consisted of a grid floor made with stainless steel bars of 0.4 cm in diameter and spaced 1.6 cm apart. The food cup was located on the front wall of the chamber, 2 cm above the floor. A retractable lever was located 2 cm to the left of the feeder and 7 cm above the floor. The other two boxes measured 23.5 cm wide, 29 cm long, and 19 cm high. The floor of these boxes was made of stainless steel bars, 0.2 cm in diameter and spaced 1 cm apart. The food cup was located on the front wall of the chamber, 2 cm above the floor. A retractable lever was located 1 cm to the left of the feeder, 6 cm above the floor. In all the boxes, lever protraction and retraction took approximately 0.25 s. Pellet dispensers delivered 45 mg Noyes pellets (rodent formula A/D). Each box was enclosed in a sound-attenuating chamber equipped with diffuse light (GE 1820), a speaker that administered white noise, and a fan for air circulation. Background masking noise (speaker and fan) was 75 dB (SPL, scale B). A computer located in an adjacent room controlled session events and recorded lever pressings. The lever was adjusted so that minimum pressure applied on its surface would close a circuit and produce a short pulse detected as a response by the computer. The duration of the lever pressure was not taken into account; each press was counted as a single response.

Procedure. Rats were randomly assigned to one of six groups ($n = 12$). The experiment was divided into two phases: preexposure and autoshaping. Rats assigned to Groups 12/1 and 12/5 received 12 sessions of preexposure to the CS; no USs were presented during these sessions. Each preexposure session included 10 CS presentations. In each of these trials, the lever was presented for a fixed 10-s duration and then withdrawn. An average intertrial interval of 90 s (range: 60-120 s) separated successive trials; a similar time interval was introduced before the first trial and after the last trial of each session. Contacts with the lever sufficient to activate a switch were counted as lever-contact responses. Prior research indicated that twelve 10-trial sessions of nonreinforced preexposure to the CS would be sufficient to produce significant evidence of the CS-preexposure effect (Boughner, 1999). Rats assigned to Groups X/1 and X/5 received 12 sessions of preexposure to the conditioning box, each one lasting 18 min (session length was matched for these four groups). Neither CSs nor USs were presented during these sessions. Finally, rats assigned to Groups OA/1 and OA/5 received no preexposure treatment, but were transported to the conditioning room, handled out of their cages, and returned to the vivarium. All groups were therefore matched in terms of these factors.

Autoshaping training started the day after the last preexposure session. During the autoshaping sessions, all the groups were treated equally. All animals received 10 sessions of autoshaping training with the same training parameters as during preexposure except that the withdrawal of the lever in each trial coincided with the delivery of either 1 or 5 pellets depending on the group. Groups 12/1, X/1, and OA/1 received one 45-mg pellet per trial. Groups 12/5, X/5, and OA/5 received five pellets per trial, delivered in rapid succession (one pellet every 0.2 s).

In all the experiments reported in this article, the number of responses per trial was transformed to a rate measure (responses per min), subjected to analysis of variance, and, where appropri-

ate, subjected to Ryan's procedure (REGWQ in SPSS; Toothaker, 1991) for ad hoc pairwise comparisons. The alpha value was set at the 0.05 level in all the statistical tests reported in this article.

Results and Discussion

The preexposure lever-contact performance of Groups 12/1 and 12/5 was characterized by within-session decrease in response rate and between-session spontaneous recovery. (Spontaneous recovery is the term used to describe the recovery of a previously habituated response that occurs after a period of rest; e.g., Thompson & Spencer, 1966.) A Group (12/1, 12/5) x Session x Trial analysis indicated only a significant decrease in responding across trials, $F(9, 198) = 19.85$. All other effects failed to reach a significant level, $F_s < 1.35$. The absence of a group effect confirms that the unconditioned response to lever presentations was similar in the two preexposed groups before the start of autoshaping training.

The results of the autoshaping phase are presented in Figure 1. The top panel shows the groups that received a single pellet per trial, whereas the bottom panel shows the groups reinforced with 5 pellets per trial. Several conclusions can be drawn from these results. First, autoshaping proceeded faster and to a higher response level with the larger, 5-pellet US than with the smaller, 1-pellet US, as was expected on the basis of prior research (Thomas et al., 1998). Second, CS-preexposure training retarded acquisition with both US magnitudes, at least relative to the context control. Third, and most importantly, whereas autoshaping after preexposure to the context was similar to original acquisition with the small US magnitude, context preexposure led to a consistently higher response level than original acquisition with the large US magnitude. A Preexposure (CS, context, none) x US Magnitude (5 pellets, 1 pellet) x Session analysis provided support for the previous conclusions. There were significant main effects for US magnitude, $F(1, 66) = 23.06$, preexposure condition, $F(2, 66) = 9.22$, and sessions, $F(9, 594) = 91.01$. There was also a significant interaction between US magnitude and sessions, $F(9, 594) = 3.91$, indicating that the size of the reward affected the rate of acquisition. All other effects were nonsignificant, $F_s < 1.96$.

A Preexposure x Session analysis on the small-US groups (Figure 1, top) yielded significant main effects for preexposure, $F(2, 33) = 4.29$, and sessions, $F(9, 297) = 41.22$, as well as a significant interaction, $F(18, 297) = 1.77$. Pairwise comparisons indicated that Group 12/1 was significantly lower than both control groups, which, in turn, did not differ from each other. A similar analysis of the large-US groups (Figure 1, bottom) provided a different pattern of results. There were significant effects for preexposure, $F(2, 33) = 6.60$, and sessions, $F(9, 297) = 54.37$, but the interaction was not significant, $F < 1$. Most importantly, CS preexposure depressed autoshaping performance significantly relative to the context-control group, but not relative to the original-acquisition control. There was also a significantly higher performance level for Group X/5 than for Group OA/5, that is, a context-preexposure effect.

The results obtained in the present experiment using a single pellet as the US were identical to the results of previous experiments carried out under similar conditions (Boughner, 1999). With five pellets as the US, however, the interpretation of the results depends on the choice of a control condition. The CS-preexposure effect was present in a comparison of a group preexposed to the CS and context with a control preexposed only to the context, but not when the auto-

shaping performance of preexposed animals was compared to the performance of original acquisition controls. This problem is aggravated by the presence of a context-preexposure effect, a fact that raises doubts as to the appropriateness of the context control condition as a comparison group to assess latent inhibition.

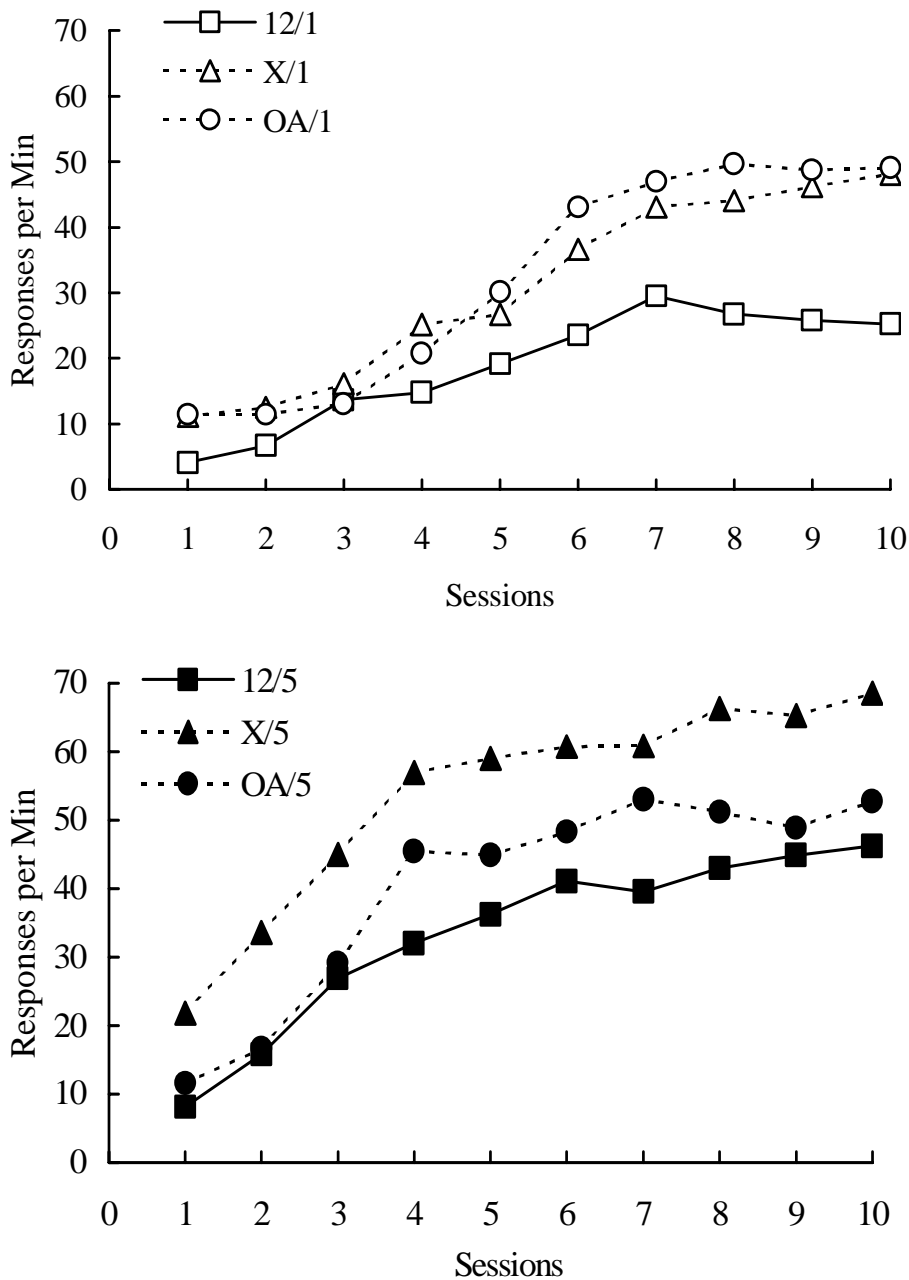


Figure 1. Lever-pressing autoshaping performance of groups preexposed to the CS during 12 sessions, preexposed to the context (X), or nonpreexposed (OA: original acquisition). Groups received autoshaping training reinforced with either one pellet per trial (top panel) or 5 pellets per trial (bottom panel). Data from Experiment 1.

Experiment 2

Experiment 2 assessed the hypothesis that the longer the nonreinforced exposure to the context, the higher the response rate during the subsequent auto-shaping phase. There is no direct available evidence for such an effect, but there is indirect evidence from experiments that manipulated nonreinforced preexposure to the CS. In such experiments, the size of the CS-preexposure effect was a direct function of the total number of nonreinforced CS presentations, independently of the distribution of preexposure trials across sessions (Albert & Ayres, 1989). It is plausible, then, that the impact of context preexposure on CS acquisition depends on the total length of the preexposure sessions (see Papini et al., 1987, for related data). Because nonreinforced preexposure to the context was expected to facilitate CS responding, this experiment was conducted under conditions of massed training with short ITIs. Massed training is known to generate low levels of behavior to the CS under conditions very similar to those used in the present experiments (Papini & Brewer, 1994; Thomas et al., 1998). Such low response levels reduces the limiting effects of response ceilings, thus providing a suitable situation to assess the impact of nonreinforced preexposure of the context on the facilitation of sign-tracking responses.

In addition, Experiment 2 provided a direct assessment of the strength of one potential competing response, namely, goal tracking. The beneficial effects of nonreinforced preexposure to the context on autoshaping performance could be mediated by changes in the extent to which contextual stimuli control the occurrence of potential competing responses at the time of conditioning (Papini & Brewer, 1994). If this were the case, one would expect not only differences in the rate of goal tracking across groups, but also a negative correlation between lever-pressing and goal-tracking responses during autoshaping.

Method

Subjects and Apparatus. The subjects were 24 male, experimentally naive Wistar rats. Twelve rats were approximately 90 days old, whereas the rest were about 180 days old at the start of the experiment. All rats were obtained from the TCU breeding colony. Housing, food deprivation, and maintenance conditions were as described in Experiment 1. A contact sensor was connected to the food cup and the grid floor. Any contact of the rat with the food cup (e.g., touching the cup with the snout or tongue) was recorded as a goal-tracking response. Other aspects of the training apparatus were as described in Experiment 1.

Procedure. Rats were matched for age and randomly assigned to one of three conditions ($n = 8$) depending on the extent of preexposure training. All the rats received 10 sessions of preexposure to the context during which no events were scheduled. Rats in Groups 200, 100, and 50 differed in the duration of each preexposure session, which was 20, 10, and 5 min long, respectively. Group labels reflect the total amount of preexposure to the context in min. Following context preexposure, all rats received 10 sessions of autoshaping training similar to those described in Experiment 1 for Group OA. There were 10 CS-US trials per session, each ending in the delivery of 5 pellets (one every 0.2 s). A relatively short ITI was implemented to induce low levels of responding; the average ITI duration was 15 s (range: 10-20 s). Lever pressings and food-cup contacts were the dependent variables in this experiment. Lever pressings were recorded as described in Experiment 1. Goal-tracking responses were measured during the 10-s presentation of the lever and during the 10-s period immediately preceding lever presentation. Statistical analyses were computed as described in Experiment 1.

Results and Discussion

Figure 2 (top panel) shows the lever-pressing results of this experiment. It is clear that extensive preexposure to the context leads to a relatively high level of massed performance, comparable to the highest levels reported in rat autoshaping experiments under a variety of conditions (e.g., Papini & Brewer, 1994; Papini & Dudley, 1993; Thomas et al. 1998). Although groups were matched in terms of age (age was not a relevant factor in this experiment), the performance of the 180-day olds was generally lower than that of the 90-day olds. However, the ordering of the groups was the same at both ages. A Group (200, 100, 50) x Age (180, 90) x Session analysis revealed a significant interaction between group and session, $F(18, 153) = 1.95$. Also significant were the main effects of group, $F(2, 17) = 9.30$, and session, $F(9, 153) = 19.54$. The age effect was detected in terms of a significant interaction of age and session, $F(9, 153) = 6.17$, and a significant age effect, $F(1, 17) = 17.65$; however, neither the interaction between group and age nor the triple interaction reached significant levels, $F_s < 1.63$. Pairwise comparisons indicated that Group 200 performed significantly above Groups 100 and 50, which, in turn, did not differ from each other in terms of lever-pressing behavior.

Figure 2 (bottom panel) shows the goal-tracking performance of each group in terms of a difference score: Contacts during the CS minus contacts before the CS. In Group 200, goal tracking was suppressed in the first session, but it exhibited little change from the pre-CS to the CS period in subsequent sessions. By contrast, Groups 50 and 100 increased the frequency of goal tracking as autoshaping training progressed. A Group x Age x Session analysis indicated significant group, $F(2, 17) = 4.54$, and session effects, $F(9, 153) = 4.91$; none of the other effects reached significance, $F_s < 1.22$. Pairwise comparisons confirmed that Group 200 performed significantly below Groups 50 and 100, which, in turn, did not differ from each other in their goal-tracking behavior.

Pearson's coefficients of correlation were computed for the average lever-pressing and goal-tracking responses during the initial and final 5 sessions of conditioning. All 24 rats were included in this analysis. Whereas the correlation was nonsignificant for sessions 1-5 of autoshaping training, $r(22) = -0.29$, the two response measures achieved a significant negative correlation during the second half of autoshaping training, $r(22) = -0.53$. The negative sign of this correlation suggests that there was competition for expression between lever-pressing and goal-tracking responses.

The main conclusion from these results is that nonreinforced preexposure to the context can dramatically enhance lever-pressing performance under conditions that would typically yield a very low level. Therefore, the effect of context preexposure on behavior in a subsequent conditioning phase can be so large that it renders a different image of the context control condition typically used in latent inhibition experiments. Rather than providing a "neutral" baseline against which to assess retardation of acquisition caused by preexposure to the CS, the context control may, under certain conditions, provide an inflated rate of acquisition that distorts the interpretation of the effects of CS preexposure.

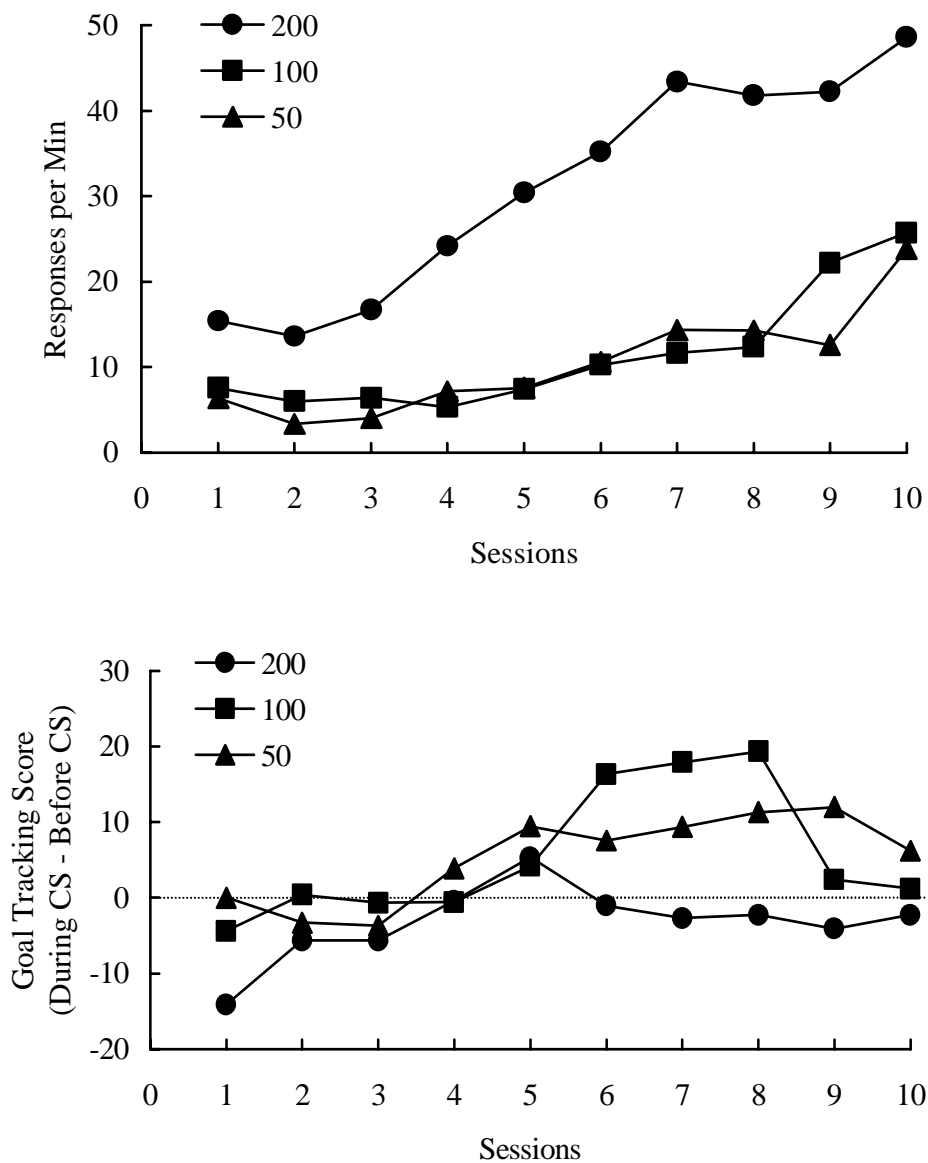


Figure 2. Lever-pressing (top panel) and goal-tracking (bottom panel) performance of groups preexposed to the context during a total of 50, 100, or 200 min. Groups OA/M and OA/S are from Experiment 3. Data from Experiment 2.

Experiment 3

Experiment 1 provided evidence for the context-preexposure effect and Experiment 2 demonstrated the context's ability to enhance massed autoshaping performance. Experiment 3 assessed the degree of specificity of the context-preexposure effect: Does it depend on nonreinforced preexposure to the training context, or to just any context? The evidence for a context-preexposure effect based on preexposure to either the training context or a nontarget context is not

particularly robust. In an appetitive experiment with rats, Channell and Hall (1983) found similar acquisition rates in groups preexposed in either the same or in a different context to that experienced during conditioning. The contexts were differentiated in terms of odor (mint vs. violet) and background white noise (presence vs. absence). Because the context switch was effective when preexposure involved the CS, it cannot be argued that the manipulation failed because rats did not discriminate the contexts. In the present experiment, contexts were differentiated in terms of odor, tactile, and visual stimuli, and the assignment to each context was counterbalanced to prevent sensory-perceptual biases from influencing autoshaping data.

Method

Subjects. The subjects were 14 male, experimentally naive Wistar rats, approximately 90 days old at the beginning of the experiment, and obtained from the TCU breeding colony. Housing, food deprivation, and maintenance conditions were as described in Experiment 1.

Apparatus. The conditioning boxes described in Experiment 1 were used in the present experiment. Two contexts were created by manipulating olfactory, tactile, and visual cues. The standard operant boxes used in Experiment 1 were labeled context X in this experiment. These same boxes were modified in the following manner to arrange for context Y. First, two drops of a peppermint oil solution were placed in the tray beneath the box's floor. The peppermint solution was prepared by mixing 5 drops of 100% Humco peppermint oil diluted in 25 ml of tap water. Second, a flat metallic plate covered the entire floor of the conditioning box. Third, the house light was turned off during the session.

Procedure. Rats were randomly assigned to 2 groups ($n = 7$). Group Same received preexposure and autoshaping training in the same context, whereas Group Diff received preexposure in one context and autoshaping in the other context. The identity of the context (whether X or Y) was counterbalanced within each group. In the first phase, both groups received 18 sessions of nonreinforced preexposure to a context in which neither the lever CS nor the food US were presented, as done in previous experiments. In Group Same, 4 rats received training in context X and 3 in context Y. In Group Diff, 3 rats received training in context X and 4 in context Y. Each of these sessions lasted for 18 min (the approximate duration of an autoshaping session in the second phase).

The same autoshaping training was administered to all the animals during the second phase of this experiment. In Group Same, autoshaping took place in the same context as preexposure (X for 4 rats, Y for 3 rats). In Group Diff, autoshaping sessions were administered in the other context relative to preexposure (X for the 4 rats preexposed to Y and Y for the 3 rats preexposed to X). Therefore, during autoshaping 4 rats received training in X and 3 in Y in each group. There were 10 autoshaping sessions and 10 CS-US trials per session; each trial ended with the response-independent delivery of 5 pellets (1 pellet per 0.2 s). Data analyses were performed as described in Experiment 1.

Results and Discussion

The results of this experiment are presented in Figure 3. The group preexposed and autoshaped in the same context exhibited the fastest acquisition rate and highest terminal performance. These rats had received extensive preexposure to the training context (a total of 18 sessions) before autoshaping training. This difference also indicates that the contexts were, in fact, discriminated. A Group (Same, Diff) x Context (X, Y) x Session analysis was computed. Context was included to assess the extent to which X and Y differentially affected autoshaping performance. The results indicated a significant Group x Session interaction, $F(9, 90) = 3.29$, as well as significant main effects of groups, $F(1, 10) = 10.22$, and sessions, $F(9, 90) =$

25.64. There was no indication that the type of context affected autoshaping performance: None of the effects involving this factor achieved a significant level, $F_s < 1.04$. This experiment supports the conclusion that the context-preexposure effect occurs because of nonreinforced preexposure to the training context, and not just to any context.

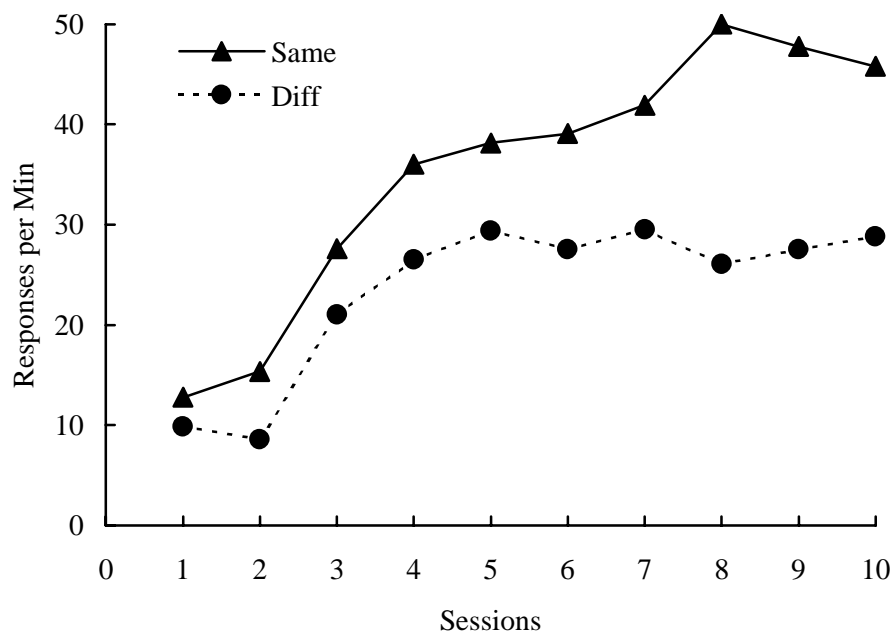


Figure 3. Lever-pressing autoshaping performance of groups preexposed and trained in either the same context (Same) or in different contexts (Diff). Context assignment was counterbalanced in each group. Data from Experiment 3.

General Discussion

Most contemporary research on the CS-preexposure effect, especially with nonhuman animals, is based on a comparison between a group preexposed to the context and the CS and one preexposed only to the context (see Table 1). Whereas the logic of this context control appears flawless at first glance, further consideration suggests that it is potentially faulty. If the same process that applies to discrete CSs also applies to contextual cues, that is, if latent inhibition can affect the ability of contextual stimuli to enter into associations with the US, then this effect may enhance conditioning of a novel CS (see introduction for references). Under such conditions, the context control offers an inflated view of acquisition, one that facilitates the finding of a CS-preexposure effect by exaggerating its size. The present experiments provide direct evidence in support of the claim that nonreinforced preexposure to the training context can have significant effects on subsequent Pavlovian conditioning occurring in the same context.

Experiment 1 demonstrated that this problem does not invalidate all illustrations of the CS-preexposure effect. If rat autoshaping is based on a 1 pellet US, then the context control provides the same picture as that provided by an original acquisition control. However, an increase in US magnitude from 1 to 5 pellets per

trial undermined the validity of the context control. With 5 food pellets per trial, acquisition was faster in a group preexposed to the context than in the original acquisition control, thus demonstrating a context-preexposure effect. Furthermore, a group preexposed to the CS was no longer discriminable from an original acquisition control. Thus, is the difference between Groups 12/5 and X/5 in Figure 1 (lower panel) a reflection of latent inhibition of the CS, as one would easily conclude if the design had not included an original acquisition control? Or is it the result of facilitated acquisition in Group X/5 by nonreinforced preexposure to the training context? If one notices that administering 5 pellets (rather than 1 pellet) generally improves autoshaping (cf. Thomas et al., 1998), and assumes that researchers interested in latent inhibition are likely to use intense USs for optimal performance, then the interpretational problem that follows from these results may affect a considerable number of published articles. The effects of environmental variables, brain lesions, and various drugs on the CS-preexposure effect, generally based on a comparison between a CS-preexposed and a context-preexposed group, may have to be reopened for empirical analysis. The suspicion is that the context control may have inflated the size of the CS-preexposure effect in the control conditions (e.g., sham lesion or saline controls), used to interpret the effects of such factors (e.g., brain lesions or drug treatments).

The methodological approach chosen in the present experiments was to also incorporate a second control condition: original acquisition. Obviously, while including two controls in any experiment may be appropriate, this does not imply that more efficient designs are not possible. Two control groups were included in Experiment 1 because we were interested in demonstrating the drawbacks of using only a context control. However, other control conditions reported in the literature appear equally suitable and even more economical than the use of two independent control groups. Consider the following possibilities. First, one group receives nonreinforced preexposure to the target stimulus, A- trials, whereas the control group receives preexposure to a nontarget stimulus, B- trials; then both groups receive reinforced training with the target stimulus, A+ (e.g., Escobar, Arcediano, & Miller, 2002). Retardation of acquisition should be specific to the preexposed CS. Second, one might use the same preexposure training as in the previous design, but instead test the effects using an A+/B- discrimination. A- preexposure should interfere with the development of the discrimination by depressing performance to A during conditioning, whereas B- preexposure should enhance the development of the discrimination by suppressing performance to B during conditioning (Abramson & Bitterman, 1986). Finally, the CS-preexposure effect could be demonstrated, in principle, using a within-group design: A- preexposure followed by A+/B+ training (e.g., Lubow & Moore, 1959). An obvious potential problem common to the use of a nontarget CS and a within-subject design is lack of sensitivity due to extensive stimulus generalization between A and B. These designs would not be open to the objections raised against the exclusive use of the context control in the introduction, provided that A and B are selected to be of similar salience, control similar acquisition rates, and are counterbalanced within each group.

The presence of the CS-preexposure effect is not only a function of the control condition chosen for comparison, as shown in Experiment 1, but also a function of the dependent measure used to assess conditioning. Boughner and Papini (2003) preexposed rats to either the CS and the training context, or just the

training context, and then administered CS-US pairings (a visual CS paired with the delivery of 5 pellets). Conditioning was assessed in terms of two different responses: Sign tracking, the tendency to approach the CS site, and goal tracking, the tendency to approach the site where food is about to be delivered. Others have shown that the outcome of a given manipulation often depends on the particular behavior chosen as the dependent variable. In particular, conditions that tend to produce little sign tracking (e.g., long CS-US delay, long CS duration) may, in some cases, produce significant amounts of goal tracking (for a review, see Domjan, 2000). Whether one concludes that such a condition supports learning may thus depend on the choice of the dependent variable. In Boughner and Papini's (2003) experiment, a typical CS-preexposure effect was found in the sign-tracking measure, but goal tracking exhibited an acquisition rate similar to that of a control group preexposed only to the context. The absence of a latent inhibition effect in the goal-tracking measure is especially compelling given Boughner and Papini's (2003) choice of a context control, which, given the present results, appears to be a conservative control condition. As a result, high goal-tracking levels despite extensive CS preexposure indicate that such preexposure does not prevent animals from responding to the CS—it just changes the form of the conditioned response. A similar conclusion is suggested by the results of Experiment 2 in which extensive preexposure to the context may have allowed for strikingly high levels of auto-shaping performance under massed conditions of training by reducing the frequency of competing goal-tracking responses.

It was also argued that magazine pretraining at the start of an experiment introduces further problems of interpretation when appetitive conditioning procedures are used. In this case, the problem lies on the administration of CS preexposure in a context previously made excitatory by magazine pretraining. This sequence of training may lead to a retardation of acquisition that can be explained in terms other than CS processing, including inhibitory conditioning and contextual blocking of the CS (see introduction). When magazine pretraining cannot be eliminated, as it is the case in most appetitive preparations, then other techniques must be implemented. For example, magazine pretraining could be administered in a different context from that used during preexposure and acquisition (e.g., Balsam & Schwartz, 1981). Another possibility used in some appetitive conditioning experiments successfully is to administer magazine pretraining after CS preexposure (e.g., Killcross & Balleine, 1996).

What do the present results say about the nature of latent inhibition? Perhaps the most important problem to resolve is why, at least under some conditions, extensive nonreinforced preexposure to the CS leads to an acquisition rate indistinguishable from that of an original acquisition control, as in Experiment 1 (see Figure 1, bottom panel, 5-pellet conditions). Some possibilities can be easily discarded. For example, it cannot be argued that the absence of a CS-preexposure effect in Experiment 1 questions the status of this phenomenon because this effect can be demonstrated with appropriate controls under slightly different conditions (see Figure 1, top panel). Similarly, it cannot be argued that the absence of a difference between preexposed and original acquisition groups in Experiment 1 is the result of a response ceiling for the original acquisition control, because the context control group performed at an even higher level (see Figure 1, bottom). A simple procedural explanation would suggest that with higher US magnitudes (or, in gen-

eral, with optimal training parameters), the detection of the CS-preexposure effect would require more extensive nonreinforced preexposure to the CS. This problem remains to be empirically studied. Notice that this explanation does not resolve the issue of the proper control conditions for latent inhibition. It would still be necessary to demonstrate that the conditions of a particular experiment do not produce a significant context-preexposure effect to justify the exclusive use of a context control. Another possibility is that optimal acquisition conditions rapidly reverse any effects of nonreinforced CS preexposure, thus reducing or eliminating the CS-preexposure effect. An analogy of this idea may be found in the phenomenon of reinstatement (Pavlov, 1927). After extinction abolishes a conditioned response, the un signaled presentation of the US is often sufficient to cause a significant recovery of the response (i.e., the reinstatement phenomenon). As applied to the present experiments, perhaps one or a few presentations of a strong US may reinstate a process that controls acquisition (e.g., normal levels of attention), thus reducing or eliminating latent inhibition. A yet untested prediction that follows from this account suggests that the CS-preexposure effect should be reversed by the delivery of a few un signaled USs in early acquisition.

A tangential point about the present results concerns the fact that nonreinforced preexposure to the CS affected the asymptotic level of performance during the autoshaping phase. Most theories of latent inhibition conceptualize this phenomenon as a retardation of acquisition, rather than both a rate and an asymptotic effect (see Lubow, 1989). Results similar to those reported here were obtained in our lab before (Boughner, 1999, 2003; Boughner & Papini, 2003), as well as in other labs (e.g., Reed, 1995). In other cases, however, CS preexposure affects the rate of acquisition, but not the final level of responding (e.g., Channel & Hall, 1983). It is unclear for the moment whether the results reported in this paper truly reflect asymptotic performance; it is plausible that further autoshaping training would eventually result in an increase in the level of responding to the CS that might eliminate what appears to be an asymptotic effect in the present data.

In conclusion, as it is the case with other learning phenomena (e.g., Papini & Bitterman, 1990, 1993), the effects of the control treatments implemented in demonstrations of latent inhibition need to be carefully reevaluated in light of the results reported in this article. The exclusive use of a context control condition can, under certain conditions, confound the effect of nonreinforced preexposure to the CS with that of nonreinforced preexposure to the context.

References

- Abramson, C. I., & Bitterman, M. E. (1986). Latent inhibition in honeybees. *Animal Learning and Behavior*, **14**, 184-189.
- Albert, M., & Ayres, J. J. B. (1989). With number of preexposures constant latent inhibition increases with preexposure CS duration or total CS exposure. *Learning and Motivation*, **20**, 278-294.
- Balaz, A. M., Capra, S., Kasprow, W. I., & Miller, R. R. (1982). Latent inhibition of the conditioning context: Further evidence of contextual potentiation of retrieval in the absence of appreciable context-US associations. *Animal Learning and Behavior*, **10**, 242-248.
- Balsam, P. D., & Schwartz, A. L. (1981). Rapid contextual conditioning in autoshaping. *Journal of Experimental Psychology: Animal Behavior Processes*, **7**, 382-393.
- Balsam, P. D., & Tomie, A. (1985) (Eds.). *Context and learning*. Hillsdale, NJ: Erlbaum.
- Batson, J. D., & Best, M. R. (1982). Lithium-mediated disruptions of latent inhibition: overshadowing by the unconditioned stimulus in flavor conditioning. *Learning and Motivation*, **13**,

167-184.

- Boughner, R. L. (1999). *Latent inhibition in autoshaping of rats*. Unpublished Master's Thesis, Texas Christian University.
- Boughner, R. L. (2003). *The relationship between latent inhibition and the partial reinforcement extinction effect*. Unpublished PhD Dissertation, Texas Christian University.
- Boughner, R. L., & Papini, M. R. (2003). Latent inhibition in rats: Now you see it (sign tracking), now you don't (goal tracking). *Learning and Behavior*, **31**, 387-392.
- Burns, M., & Domjan, M. (2001). Topography of spatially directed conditioned responding: Effects of context and trial duration. *Journal of Experimental Psychology: Animal Behavior Processes*, **27**, 269-278.
- Channell, S., & Hall, G. (1983). Contextual effects in latent inhibition with an appetitive conditioning procedure. *Animal Learning and Behavior*, **11**, 67-74.
- Coutureau, E., Léna, I., Daugé, V., & Di Scala, G. (2002). The entorhinal cortex-nucleus accumbens pathway and latent inhibition: A behavioral and neurochemical study in rats. *Behavioral Neuroscience*, **116**, 95-104.
- De La Casa, L. G., & Lubow, R. E. (2000). Super-latent inhibition with delayed conditioned taste aversion testing. *Animal Learning and Behavior*, **28**, 389-399.
- Domjan, M. (2000). General process learning theory: Challenges from response and stimulus factors. *International Journal of Comparative Psychology*, **13**, 101-118.
- Escobar, M., Arcediano, F., & Miller, R. R. (2002). Latent inhibition and contextual associations. *Journal of Experimental Psychology: Animal Behavior Processes*, **28**, 123-136.
- Grant, M. J., & Young, D. (1971). The effects of preexposure to learning apparatus. *Behavior Research Methods and Instrumentation*, **3**, 251-252.
- Hinderliter, C. F., & Misanin, J. R. (1993). Context familiarity and delayed conditioned taste aversion in young-adult and old-age rats. *Perceptual and Motor Skills*, **77**, 1403-1406.
- Killcross, S., & Balleine, B. (1996). Role of primary motivation in stimulus preexposure effects. *Journal of Experimental Psychology: Animal Behavior Processes*, **22**, 32-42.
- Lubow, R. E. (1989). *Latent inhibition and conditioned attention theory*. Cambridge, UK: Cambridge University Press.
- Lubow, R. E., & Moore, A. U. (1959). Latent inhibition: The effect of nonreinforced preexposure to the conditional stimulus. *Journal of Comparative and Physiological Psychology*, **52**, 415-419.
- Lubow, R. E., Schnur, P., & Rifkin, B. (1976). Latent inhibition and conditioned attention theory. *Journal of Experimental Psychology: Animal Behavior Processes*, **2**, 163-174.
- Mackintosh, N. J. (1973). Stimulus selection: Learning to ignore stimuli that predict no change in reinforcement. In R. A. Hinde & J. Stevenson-Hinde (Eds.), *Constraints on learning* (pp. 75-96). New York: Academic Press.
- Papini, M. R., & Bitterman, M. E. (1990). The role of contingency in classical conditioning. *Psychological Review*, **97**, 396-403.
- Papini, M. R., & Bitterman, M. E. (1993). The two-test strategy in the study of inhibitory conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, **19**, 342-352.
- Papini, M. R., & Brewer, M. (1994). Response competition and the trial-spacing effect in autoshaping with rats. *Learning and Motivation*, **25**, 201-215.
- Papini, M. R., & Dudley, R. T. (1993). Effects of number of trials per session on autoshaping in rats. *Learning and Motivation*, **24**, 175-193.
- Papini, M. R., Linwick, D., & Overmier, J. B. (1987). Preconditioning exposure to contextual cues and the acquisition of the keypeck behavior in autoshaping with pigeons. *Bulletin of the Psychonomic Society*, **25**, 486-488.
- Pavlov, I. P. (1927). *Conditioned reflexes*. Oxford, UK: Oxford University Press.
- Pearce, J. M., & Hall, G. (1980). A model for Pavlovian learning: Variations in the effectiveness of conditioned but not of unconditioned stimuli. *Psychological Review*, **87**, 532-552.
- Reed, P. (1995). Enhanced latent inhibition following compound pre-exposure. *Quarterly Journal of Experimental Psychology*, **48B**, 32-45.
- Reed, P., & Tsakanikos, E. (2002). The influence of a distractor during compound preexposure on latent inhibition. *Animal Learning and Behavior*, **30**, 121-131.
- Reilly, S. (1987). Hyperstriatal lesions and attention in the pigeon. *Behavioral Neuroscience*, **101**, 74-86.
- Rescorla, R. A. (1979). Conditioned inhibition and extinction. In A. Dickinson & R. A. Boakes (Eds.), *Mechanisms of learning and motivation* (pp. 83-110). Hillsdale, NJ: Erlbaum.

Rudy, J. W., Kranter, E. E., & Gaffuri, A. (1976). Attenuation of the latent inhibition effect by prior exposure to another stimulus. *Journal of Experimental Psychology: Animal Behavior Processes*, **2**, 235-247.

Thomas, B., Huneycutt, D., & Papini, M. R. (1998). Reward magnitude but not time of day influences the trial-spacing effect in autoshaping in rats. *Physiology and Behavior*, **65**, 423-427.

Thompson, R. F., & Spencer, W. A. (1966). Habituation: A model phenomenon for the study of neuronal substrates of behavior. *Psychological Review*, **73**, 16-43.

Tomie, A. (1976). Interference with autoshaping by prior context conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, **2**, 323-334.

Toothaker, L. (1991). *Multiple comparisons for researchers*. Newbury Park, CA: Sage.

Tranberg, D. K., & Rilling, M. (1978). Latent inhibition in the autoshaping paradigm. *Bulletin of the Psychonomic Society*, **11**, 273-276.

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