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Learning and Motivation 37 (2006) 42–65

**Learning  
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Motivation**

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## Some determinants of latent inhibition in human predictive learning <sup>☆</sup>

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Received 24 September 2004; received in revised form 31 January 2005

Available online 1 April 2005

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### Abstract

The present experiments assessed the effects of different manipulations between cue preexposure and cue-outcome pairings on latent inhibition (LI) in a predictive learning task with human participants. To facilitate LI, preexposure and acquisition with the target cues took place while participants performed a secondary task. Presentation of neither the target cues nor the target outcome was anticipated based on the instructions. Experiment 1 demonstrated the LI effect in the new experimental preparation. Experiment 2 analyzed the impact on LI of different activities that participants performed during the interval between preexposure and acquisition. Experiment 3 assessed LI as a function of changes in the secondary task cues made between preexposure and acquisition, namely presenting novel cues and reversing the cue-outcome contingencies. All of the manipulations in Experiments 2 and 3 resulted in a decrease in LI. The

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<sup>☆</sup> Oskar Pineño was supported by a postdoctoral fellowship from the Spanish Ministry of Education (Ref. EX2002-0739). Luis Gonzalo de la Casa was supported by Grant BSO2002-01136 from the Spanish Ministry of Science and Technology. We thank Jeffrey C. Amundson, Olga Lipatova, Gonzalo P. Urcelay, Kouji Urushihara, Miguel A. Vadillo, and Daniel S. Wheeler for their insightful comments on an earlier version of this manuscript, as well as Estrella Díaz and Olga Lipatova for their assistance in running the experiments.

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attenuation of LI by these manipulations challenges most current theories of learning and is best accommodated by Conditioned Attention Theory (Lubow, Weiner, & Schnur, 1981).

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*Keywords:* Latent inhibition; Human predictive learning; Associative models of learning

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Latent inhibition (LI, also known as the cue-preexposure effect) refers to the retarded acquisition of conditioned responding to a cue during pairings with an outcome due to the cue's previous presentations without the outcome (Lubow & Moore, 1959; see Lubow, 1973, 1989, for reviews). In a LI design, the target cue is repeatedly presented alone during an initial experimental phase (i.e., preexposure phase) and paired with an outcome in a second phase (i.e., acquisition phase). LI is said to have occurred when the rate of acquisition of responding to the preexposed cue during cue-outcome pairings is retarded, in comparison to the acquisition of responding to a novel cue (i.e., a cue that was not previously preexposed). The LI effect has become a key phenomenon in the analysis of animal conditioning, due to efforts to explain LI having encouraged the development of a number of models of learning (e.g., Lubow, Weiner, & Schnur, 1981; Mackintosh, 1975; Pearce & Hall, 1980).

To illuminate the theoretical basis of LI, the present experiments investigated the impact of different experimental manipulations interpolated between cue-alone preexposure and cue-outcome pairings. In the animal conditioning literature, researchers have shown that various manipulations other than the cue preexposure and cue-outcome pairings affect LI in divergent ways, depending on the specific manipulations and when they are interpolated during the experiment (i.e., before preexposure, between preexposure and acquisition, or between acquisition and testing). When LI was assessed using a two-phase design (i.e., preexposure and acquisition, with the acquisition phase also serving as the test phase), manipulations between preexposure and acquisition have generally attenuated LI. For example, LI has been attenuated by interpolating a retention interval (e.g., Hall & Minor, 1984; Rosas & Bouton, 1997; Wagner, 1979; Westbrook, Bond, & Feyer, 1981), performing a contextual switch (e.g., Hall & Channell, 1985, 1986; Lovibond, Preston, & Mackintosh, 1984; Westbrook, Jones, Bailey, & Harris, 2000), or presenting novel stimulation (e.g., Escobar, Arcediano, & Miller, *in press*; Lantz, 1973; Rudy, Rosenberg, & Sandell, 1977). In contrast, in studies of LI using a three-phase design (i.e., preexposure, acquisition, and test), most manipulations have been administered between acquisition and testing and have yielded divergent results. Some of these studies found LI to be attenuated by interpolation of a retention interval between acquisition and testing (e.g., Aguado, Symonds, & Hall, 1994; Bakner, Strohen, Nordeen, & Riccio, 1991; De la Casa & Lubow, 1995; Kraemer & Ossenkopp, 1986; Kraemer, Randall, & Carbary, 1991; Kraemer & Roberts, 1984; Kraemer & Spear, 1992; Westbrook et al., 2000) or presentation of a novel stimulus (e.g., Killcross, 2001). However, LI has been also found to be enhanced when a retention interval is interpolated between acquisition and testing (i.e., the so-called

super-LI effect, De la Casa & Lubow, 2000, 2002; Lubow & De la Casa, 2002; Wheeler, Stout, & Miller, 2004) or even when testing is conducted in a context different from the context of preexposure and acquisition (e.g., Swartzentruber & Bouton, 1992; Westbrook et al., 2000).

Despite the considerable interest in these variables within the animal conditioning literature, few attempts have been made to assess the impact of the aforementioned manipulations on human associative learning. Among these, attenuation of LI has been achieved by conducting preexposure and acquisition in different contexts (Escobar, Arcediano, & Miller, 2003; Gray et al., 2001; Zalstein-Orda & Lubow, 1995), as well as by interpolating a retention interval between preexposure and acquisition (Escobar et al., 2003). The interpolation of a retention interval between acquisition and test has also been shown to enhance LI in human learning (Stout, Amundson, & Miller, *in press*). Apart from these studies, to our knowledge, no further attempts have been made to investigate the factors determining the expression of LI in humans.

This lack of extensive research concerning factors that influence LI in human learning is surprising because, although empirical evidence and theoretical accounts originating in the animal conditioning literature are often applied to human learning, the direct study of the determinants of LI in humans seems necessary to clarify its similarities with LI in nonhumans. Additionally, experiments on LI with humans should also study the impact of new manipulations, which have no precedent in the animal conditioning literature, thereby surpassing mere replication.

Toward these goals, Experiment 1 was designed to demonstrate LI in a human predictive learning preparation. Experiment 2 studied the impact of an interval between the preexposure and acquisition phases on LI, while assessing whether LI would be differentially affected as a function of the activity that participants were required to perform during this interval. Finally, Experiment 3 evaluated the impact of changes between preexposure and acquisition in the relationships of nontarget cues in the ongoing masking task.

## **Experiment 1**

Experiment 1 used a two-phase within-subject methodology to establish LI in a behavioral preparation designed to study human predictive learning. In Phase 1 (cue preexposure), one of the two target cues was preexposed and task-irrelevant while the participant engaged in a masking task. In Phase 2 (acquisition), the preexposed cue (X) and a novel cue (Y) were separately paired with a positive outcome. LI would be evidenced by the retarded acquisition of responding to the X cue relative to the Y cue.

### *Method*

#### *Participants and apparatus*

The participants were 21 students [5 men and 16 women, with a mean age of 18.19 years (SEM=0.13)] from an introductory psychology course at the University of Seville. The experiment used personal computers located in a large room that allowed

for simultaneous running of about 12 participants. Participants were seated about 2 m apart, and stimuli between adjacent participants were counterbalanced.

### *Design and procedure*

*Preexposure phase.* All participants began the experiment with the masking task,<sup>1</sup> which was the same as that previously used by Pineño and Miller (2004; also see Pineño, Ortega, & Matute, 2000; Pineño & Matute, 2000). After being seated in front of the computer screen, they were shown the following instructions (in Spanish).

#### *Screen 1*

Imagine that you are a soldier for the United Nations. Your mission consists of rescuing a group of refugees that are hidden in a ramshackle building. The enemy has detected them and has sent forces to destroy the building. But the refugees rely on your cunning to escape the danger zone before that happens.

You have several trucks to rescue the refugees, and you have to place them in those trucks. In order to place people in the trucks, you must click with the mouse on the button labeled as “Place people in the truck,” so that one person per click is placed in a truck.

If you rescue a number of people on a given trip, they will arrive to their destination alive, and you will be rewarded with a point for each person. You must gain as many points as possible.

#### *Screen 2*

But your mission will not be as simple as it seems. The enemy knows of your movements and could have placed deadly mines on the road. If the truck hits a mine, it will explode, and the passengers will die. Each dead passenger will count as one negative point for you.

Fortunately, the colored lights on the Spy-Radio will indicate the state of the road. The lights can indicate that:

- (a) The road will be free of mines. → The occupants of the truck will be liberated. → You will gain points.
- (b) The road will be mined. → The occupants of the truck will die. → You will lose points.
- (c) There are no mines, but the road is closed. → The occupants of the truck will neither die nor be liberated. → You will neither gain nor lose points: You will maintain your previous score.

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<sup>1</sup> The preparation used in each of the present experiments can be downloaded from <http://www.opineno.com/task.htm>.

### Screen 3

At first, you will not know what each colored light on the Spy-Radio means. However, as you gain experience with them, you will learn their meanings.

Thus, we recommend that you:

- (a) Place more people in the truck as you become more certain that the road that you are on is free of mines.
- (b) Place less people in the truck the more certain you are that the road is mined.

Finally, it is important to know that your mission may occur in several different places. Please pay attention to the message that indicates the place in which you are.

In the previously cited experiments using this task, these instructions provided the scenario for the critical task that participants were asked to perform (i.e., to help a group of refugees escape from a war zone in trucks). However, in the present series of experiments, this task merely provided a scenario in which participants could receive additional treatments that were not mentioned in the instructions. That is, the instructed task served as a masking task, which is usually considered necessary to obtain LI with human adults (e.g., De la Casa & Lubow, 2001; Graham & McLaren, 1998; Hulstijn, 1978; Lubow & Gewirtz, 1995; but see Escobar et al., 2003).

The top of the screen, representing the spy-radio console, consisted of a gray horizontal panel on which six colored lights could be presented. Cues A and B were blue and yellow lights, counterbalanced. On each trial, a randomly chosen light position was illuminated with the color of that trial's cue (blue or yellow). Cue durations were 4 s. During the 4-s intertrial intervals, all the lights were turned off. While a light was on, each response (i.e., clicking with the mouse on an on-screen button labeled "Place people in the truck") placed one refugee in the fictitious truck. The number of refugees collected in the truck during the cue was reported in a box on the screen, with this number being immediately updated after each response. On each trial, the termination of the cue coincided with the presentation of the outcome, as described below.

Outcome 1 (O1) consisted of (a) the message "[#] refugees safe!!!" (with [#] being the number of refugees placed in the truck during the cue presentation), and (b) the participant's gaining one point for each saved refugee. The O1 message was accompanied by the presentation of a happy-face icon. Outcome 2 (O2) consisted of (a) the message "[#] refugees have died!!!", and (b) the participant's losing one point for each refugee who died in the truck. The O2 message was accompanied by the presentation of a tombstone icon. The outcome message remained on the screen for 4 s. Presumably, the more confident participants were that the trip would be successful (i.e., O1 would occur), the greater the number of refugees they would place in the truck; whereas the more certain they were that the truck would be destroyed by a mine (i.e., O2 would occur), the smaller the number of refugees they would board. A score panel on the screen showed the number of people that the participant had placed in the

truck on each trial and that number remained visible until the end of the outcome message. Clicks on the “Place people in the truck” button that occurred while the outcome message was present had no consequence. At the termination of the outcome message, this panel was reset to 0. Responses that occurred during the intertrial intervals also had no consequence and were not reflected on the panel.

Although contexts were not manipulated in the present experiments, in order to minimize differences from previous experiments using this preparation, the name of a fictitious town (i.e., Bow Town), presented together with a picture of a ramshackle building, was presented on the computer screen. The name of the town and its corresponding picture, present during trials and intertrial intervals, were shown in the middle of the screen just below the cue light panel. The picture of the building was  $1.70 \times 1.35$  cm (w  $\times$  h), and it was presented to the right of the name of the town.

While the participants were engaged in the masking task, a  $2 \times 2$  cm square icon could appear on the screen. For any given subject the icon was either blue with a black spot embedded in it, or brown with a smaller green square in it. The assignment of these icons as cues X and Y was counterbalanced. During the preexposure phase, there were 30 4-s presentations of cue X, interspersed among the intertrial intervals of the truck loading task. Cue X was followed by no outcome. The dependent variables in the preexposure phase were the number of responses to masking task cues A and B. Trials containing presentations of X, A, and B were pseudorandomly interspersed.

#### *Acquisition phase*

The acquisition phase immediately followed the preexposure phase. Although not anticipated from the instructions, participants now could gain medals by clicking on the “Place people in the truck” button during the presentation of the X and Y icons. During the acquisition phase, cues X and Y were both followed by the presentation of an outcome (+), which consisted of a message: “[#] honor decorations gained!!!” with [#] being the number of clicks on the “Place people in the truck” button during presentation of X or Y. The outcome message, accompanied by the presentation of a medal icon, lasted for 4s. Trials involving X and Y were separated from the next trials by 4-s intervals. Trials containing X, Y, A, and B were pseudorandomly interspersed. The dependent variables were the numbers of clicks on the “Place people in the truck” button during presentations of X and Y. Presumably, the more certain participants were that clicking on this button would result in gaining medals during presentations of X and Y, the more responses they would make.

In summary, Experiment 1 used a within-subject design for the assessment of LI. In the preexposure phase, participants were given 10 A-O1 and 10 B-O2 pairings in a pseudorandom sequence (the masking task). During this phase, they also were given 30 presentations of cue X always followed by no outcome. During the subsequent acquisition phase, participants received 10 reinforced presentations of cues X and Y, interspersed with 5 A-O1 and 5 B-O2 pairings in a pseudorandom sequence.

#### *Pre-analysis treatment of the data*

As in previous studies using this task (e.g., Pineño & Matute, 2000; Pineño, Ortega, & Matute, 2000), we used a selection criterion in order to ensure that participants were

attending to the experiment and that they had learned to discriminate between the masking task cues that signaled refugees saved (appetitive outcome) and refugees died (aversive outcomes). According to this criterion, the number of responses given to cue A on its last presentation in the acquisition phase had to be higher than the number of responses given to cue B on its last presentation in the acquisition phase. Based on this criterion, no participant was eliminated from Experiment 1. An alpha level of  $p < .05$  was adopted for all statistical analyses. All simple comparisons were performed using Bonferroni's post hoc tests.

*Results and discussion*

*Masking task cues*

The top panel of Fig. 1 depicts responding to the masking task cues (A and B) during the preexposure and acquisition phases. As can be seen, participants quickly learned to discriminate between these cues, responding to the appetitively reinforced cue (A) more strongly than to the aversively reinforced cue (B). A 2 (Cue: A vs. B)  $\times$  15 (Trials) ANOVA on the mean number of responses showed main effects of cue,  $F(1, 20) = 508.72, p < .001$ , and trials,  $F(14, 280) = 24.33, p < .001$ , as well as a

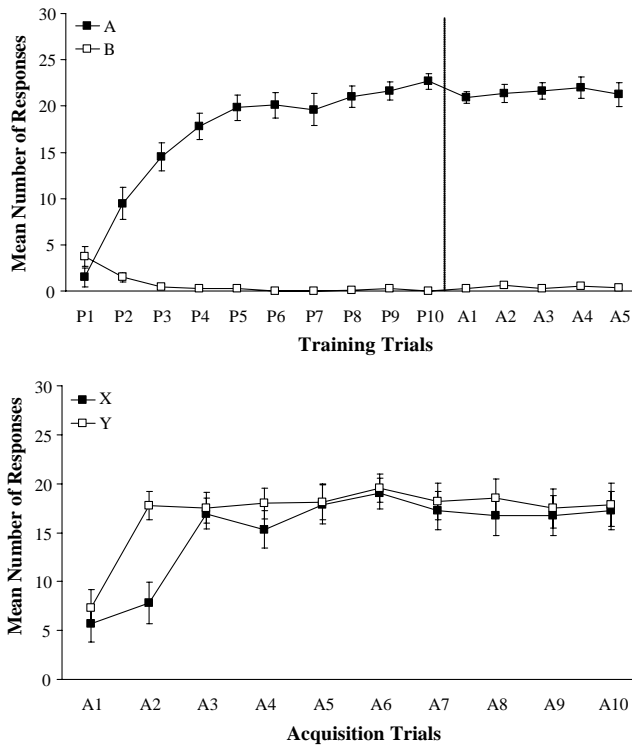


Fig. 1. Mean number of responses to the masking task cues, A and B (top panel), and to the target cues, X and Y (bottom panel), in Experiment 1. Trial numbers preceded by 'P' and 'A' represent preexposure and acquisition trials, respectively. The vertical line separates preexposure trials from acquisition trials. Error bars depict standard error of the means.

Cue  $\times$  Trials interaction,  $F(14, 280) = 37.68$ ,  $p < .001$ . Therefore, responding to the masking task cues A and B proceeded as expected. Participants rapidly learned to respond to cue A while suppressing responding to cue B. This indicates that participants attended to the masking task throughout the experiment.

### *Target task cues*

The central results (i.e., responding to the target cues X and Y) are depicted in the bottom panel of Fig. 1. As can be seen, at least on Trial A2, responding to the preexposed cue X was less than to the novel cue Y; that is LI occurred. This impression was confirmed by a 2 (Cue: X vs. Y)  $\times$  10 (Trials) ANOVA on the mean number of responses, which revealed main effects of cue,  $F(1, 20) = 5.41$ ,  $p < .05$ , and trials,  $F(9, 180) = 12.03$ ,  $p < .001$ , as well as a Cue  $\times$  Trials interaction,  $F(9, 180) = 4.40$ ,  $p < .001$ . Post hoc comparisons showed that responding to X was weaker than responding to Y only on Trial A2. On the rest of the trials (i.e., Trials A1 and A3–A10), no difference was observed. Therefore, LI was obtained immediately after the initial acquisition trial and vanished after the second acquisition trial. This short-lived LI effect is not completely surprising. During the preexposure phase, the to-be-target and masking task cues were presented on separate trials. As a consequence, the target cues may have gained more than the usual amount of attention that is allotted to them when the two sets of stimuli are presented simultaneously. Indeed, LI has not been obtained when full attention is allotted to the preexposed to-be target stimulus, as with a zero-load masking task (e.g., Braunstein-Bercovitz & Lubow, 1998).

## **Experiment 2**

Experiment 1 was successful in finding evidence of LI in a human contingency learning preparation. Experiment 2 departed from this observation and was designed to study the impact of interpolating a retention interval between preexposure and acquisition (see Escobar et al., 2003, for a similar manipulation with humans but in a Pavlovian preparation). In addition to manipulating the time between the preexposure and acquisition phases (NoDelay or 5 min), there were two groups in the long-interval condition. One group remained seated during the interval (group Stay), but the other group left the room and then returned (group Reseat).

If the interval in condition Stay had the same effect on LI as in previous experiments conducted with humans (e.g., Escobar et al., 2003), LI should be attenuated. However, if the Reseat manipulation primed the first-learned meaning of the cue by recreating the conditions prevailing at initiation of the preexposure phase, then it should either have no effect on LI (i.e., if the cue-alone memory was already strongly primed immediately before the retention interval) or it should enhance LI (i.e., if priming of the cue-alone memory immediately before the retention interval was incomplete). Alternatively, the Reseat manipulation could disrupt the transition between the preexposure and acquisition phases more strongly than did the retention interval itself. In this latter case, LI would be attenuated in conditions Stay and Reseat, but the attenuation would be stronger in the latter than in the former condition. Finally, spending the retention interval in the experimental

Table 1  
Design of Experiment 2

Group	Preexposure	Retention interval	Acquisition
NoDelay	10 A → O1/10 B → O2/30 X	None	5 A → O1/5 B → O2/5 X+/5 Y+
Stay	10 A → O1/10 B → O2/30 X	Delay	5 A → O1/5 B → O2/5 X+/5 Y+
Reseat	10 A → O1/10 B → O2/30 X	Reseat	5 A → O1/5 B → O2/5 X+/5 Y+

*Note.* A and B were the masking task cues. Presentations of A were always followed by an appetitive outcome (O1), whereas presentations of B were always followed by the aversive outcome (O2). X and Y were the target cues. '+' was an appetitive outcome, different from O1, whereas X alone denotes the absence of any outcome. Instructions were provided for the masking task but not the target task. Both Delay and Reseat conditions were administered as a 5-min retention interval, in which participants were requested to either stay seated (Delay) or leave the room and wait in the hallway (Reseat). Trial types separated by a slash were interspersed. The numbers denote the number of presentations of each trial type in each phase. See text for details.

context (condition Stay) could result in extinction of the context–cue association. According to some current theories of learning (see General discussion), this association, which is presumably formed during the preexposure phase, is responsible for the occurrence of LI. Thus, LI attenuation in condition Stay might be the result of extinction of the context–cue association, an extinction that could not occur in the Reseat condition (i.e., because the interval was spent outside the experimental context). In short, this view would predict the attenuation of LI in condition Stay, but not in condition Reseat.

### *Method*

#### *Participants and apparatus*

The participants were 58 students (27 men and 31 women, with a mean age of 19.22 years [SEM = 0.25]) from an introductory psychology course at SUNY-Binghamton, who participated in this experiment in partial fulfillment of a course requirement. Participants were assigned to one of three groups, resulting in 20 participants each in groups NoDelay and Reseat, and 18 in group Stay. The experiment was conducted using personal computers housed in individual cubicles.

#### *Design and procedure*

Unless otherwise stated, all of the procedural details were identical to those of Experiment 1. However, since Experiment 1 showed that LI dissipated by the third acquisition trial, Experiment 2 presented five (instead of 10) X+ and Y+ trials during the acquisition phase. Table 1 summarizes the design. In group NoDelay, the transition between preexposure and acquisition proceeded with no disruption, thus providing a replication of Experiment 1, whereas in groups Stay and Reseat a 5-min retention interval was interpolated between these two phases. During the retention interval, group Stay was given the following instructions<sup>2</sup> (with text in yellow font on a black screen):

<sup>2</sup> Participants generally need a cover story concerning the disruption of events caused by the retention interval. Otherwise, they might infer that the computer program failed and leave the experimental room to inquire of the experimenter.

You now have a chance to have a rest. When this black screen disappears you will be allowed to continue your mission as you have been doing until now.

After 5 min, this screen of instructions was cleared and participants in group Stay were able to proceed with the experimental task. Group Reseat, by contrast, was given the following instructions (also with text in yellow font on a black screen):

You now have a chance to have a rest. Please exit the room and wait in the hallway.

After reading the instructions, Reseat participants left the room. They were accompanied by the experimenter into the hallway, where they were asked to wait. After 5 min, they were called back and allowed to proceed with the experimental task.

### *Pre-analysis treatment of the data*

Using the selection criterion of Experiment 1, two participants were eliminated from the data analysis (one from each of groups Stay and Reseat).

### *Results and discussion*

#### *Masking task cues*

Responding to the masking task cues (A and B) is depicted in Fig. 2. As in the previous experiment, participants quickly learned to discriminate between these cues in that responding to the appetitively reinforced cue (A) was stronger than to the aversively reinforced cue (B). Interestingly, on the first trial of the acquisition phase (Trial A1), responding to cue A was apparently weaker in groups Stay and Reseat than in group NoDelay, presumably due to the 5 min retention interval. However, as can be seen in Fig. 2, the impact of the retention interval on responding to cue A was transitory.

These impressions were confirmed by a 3 (Group: NoDelay vs. Stay vs. Reseat)  $\times$  2 (Cue: A vs. B)  $\times$  15 (Trials) ANOVA on the mean number of responses, which yielded main effects of cue,  $F(1, 53) = 1501.76$ ,  $p < .001$ , and trials,  $F(14, 742) = 79.42$ ,  $p < .001$ . This ANOVA also revealed a Group  $\times$  Trial interaction,  $F(28,$

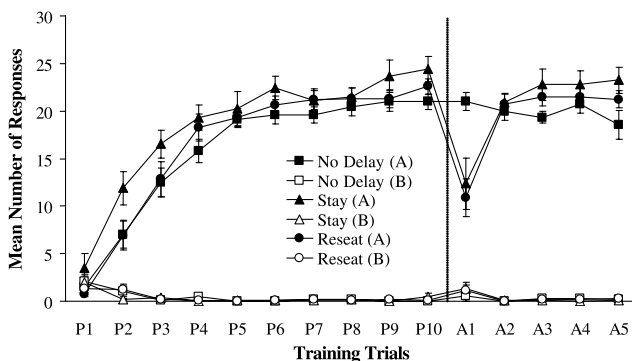


Fig. 2. Mean number of responses to the masking task cues, A and B, in Experiment 2. Trial numbers preceded by 'P' and 'A' represent preexposure and acquisition trials, respectively. The vertical line separates preexposure trials from acquisition trials. Error bars depict standard error of the means.

742) = 2.92,  $p < .001$ , a Cue  $\times$  Trial interaction,  $F(14, 742) = 102.00$ ,  $p < .001$ , and a three-way interaction,  $F(28, 742) = 3.57$ ,  $p < .001$ . Neither the main effect of group nor the Group  $\times$  Cue interaction was significant,  $ps > .17$ . Post hoc comparisons were performed in order to further assess the impact of our critical manipulation on responding to masking cues A and B on Trial A1. These comparisons revealed that, on trial A1, responding to A was stronger than responding to B in all groups. However, these comparisons found no difference in responding to either A or B among groups.<sup>3</sup>

#### *Target task cues*

The principal results are depicted in Fig. 3. As can be seen, LI is evident in group NoDelay, but not in group Reseat. In group Stay, LI appears to be intermediate between the other two groups. These impressions were supported by a 3 (Group: NoDelay vs. Stay vs. Reseat)  $\times$  2 (Cue: X vs. Y)  $\times$  5 (Trial) ANOVA on the mean number of responses, which revealed main effects of cue,  $F(1, 53) = 9.09$ ,  $p < .005$ , and trial,  $F(4, 212) = 177.57$ ,  $p < .001$ , as well as Group  $\times$  Cue,  $F(2, 53) = 4.50$ ,  $p < .05$ , and Cue  $\times$  Trial,  $F(4, 212) = 12.34$ ,  $p < .001$ , interactions. Most importantly, there was a three-way interaction,  $F(8, 212) = 3.25$ ,  $p < .005$ . The main effect of Group and the Group  $\times$  Trial interaction were not significant,  $ps > .42$ . Post hoc comparisons were performed to compare responding to X and Y on each acquisition trial, and within each group. These comparisons revealed that LI (fewer responses to X than to Y) was obtained in group NoDelay only on Trial A2. In groups Stay and Reseat, responding to X was comparable to responding to Y on all acquisition trials. In other words, compared to group NoDelay, LI was attenuated in groups Stay and Reseat. Moreover, planned comparisons showed that the difference in responding to X and Y on Trial 2 was comparable in groups Stay and Reseat ( $p > .20$ ). However, the difference between the number of responses to X and Y at test was marginally higher in group NoDelay than in group Stay,  $F(1, 53) = 3.71$ ,  $p = .059$ , whereas it was significantly higher in group NoDelay relative to group Reseat,  $F(1, 53) = 10.98$ ,  $p < .01$ .

These results indicate that the interpolation of a 5-min retention interval was sufficient to attenuate LI. This finding is congruent with those reported with Pavlovian conditioning using humans (e.g., Escobar et al., 2003) and rats (e.g., Hall & Minor, 1984; Rosas & Bouton, 1997; Wagner, 1979; Westbrook et al., 1981) as subjects. The interpolation of a retention interval, during which participants were asked to leave the experimental room (group Reseat), also attenuated LI (see bottom panel of Fig. 3). If the reseat manipulation had recreated some of the initial conditions of the experiment, enhanced LI (assuming that LI was not already maximal) should have been observed in this group. However, the reseat manipulation had a decremental impact on LI that was similar to that of the retention interval alone in group Stay.

<sup>3</sup> The lack of difference in responding to A on Trial A1 between group NoDelay and both groups Stay and Reseat might be due to our having used a strict and conservative test (i.e., Bonferroni's test). In fact, more consistent with the impressions from Fig. 2, planned comparisons found that, on Trial A1, responding to A was stronger in group NoDelay than in both groups Stay,  $F(1, 53) = 9.86$ ,  $p < .01$ , and Reseat,  $F(1, 53) = 14.28$ ,  $p < .01$ . Also, responding to A was comparable in groups Stay and Reseat,  $p > .60$ .

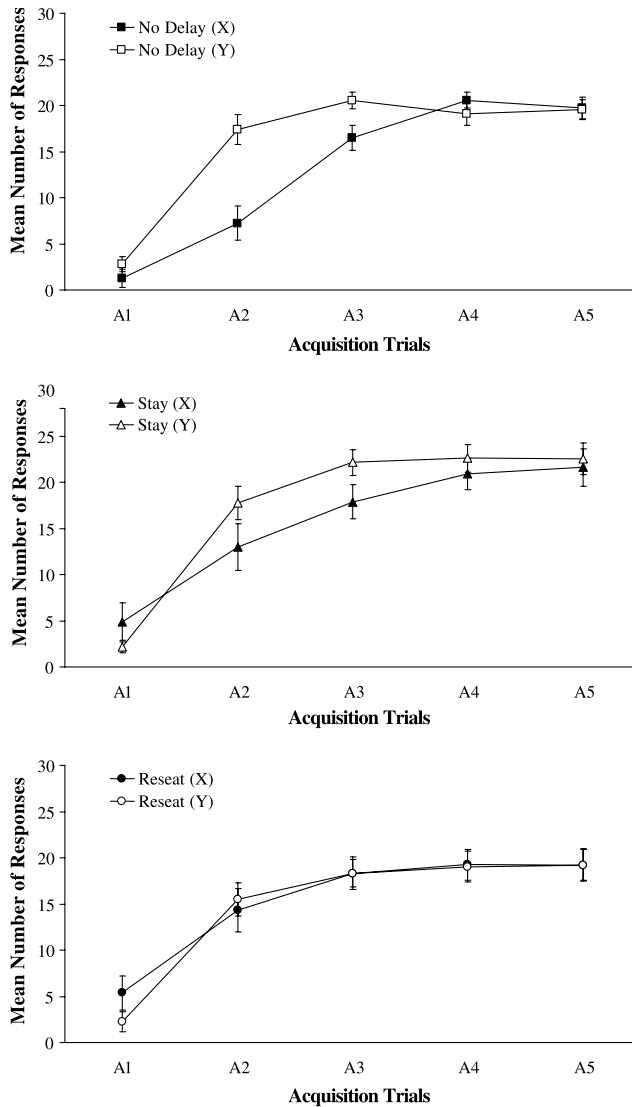


Fig. 3. Mean number of responses to the target cues, X and Y, during acquisition in Experiment 2 sorted by group. The top, middle, and bottom panels depict responding to both cues in group NoDelay, Stay, and Reseat, respectively. Although only acquisition trials are depicted, trial numbers are preceded by 'A' (i.e., acquisition trials) for the sake of clarity. Error bars depict standard error of the means.

### Experiment 3

Consistent with evidence from the Pavlovian literature, Experiment 2 found attenuation of LI as a result of interpolating a retention interval between preexposure and

Table 2  
Design of Experiment 3

Group	Preexposure	Acquisition
Same	10 A → O1/10 B → O2/30 X	5 A → O1/5 B → O2/5 X+/5 Y+
NewCues	10 A → O1/10 B → O2/30 X	5 C → O1/5 D → O2/5 X+/5 Y+
Reversal	10 A → O1/10 B → O2/30 X	5 A → O2/5 B → O1/5 X+/5 Y+

*Note.* A, B, C, and D were the masking task cues. X and Y were the target cues. '+' was an appetitive outcome, different from O1, whereas X alone denotes the absence of any outcome. Instructions were provided for the masking task but not for the target task. Trial types separated by a slash were interspersed. The numbers denote the number of presentations of each trial type in each phase. See text for details.

acquisition but this time in a human predictive learning preparation. Experiment 3 looked for another possible parallel between human predictive learning and Pavlovian conditioning in factors that attenuate LI. There have been many reports of animal conditioning studies in which LI was attenuated by the presentation of novel stimulation between preexposure and acquisition (e.g., Escobar et al., *in press*; Lantz, 1973; Rudy et al., 1977). Toward examining this effect in human predictive learning, in Experiment 3 the effect of changing the masking task between preexposure and acquisition was evaluated. Thus, in addition to their roles as masking task cues, A and B provided a potential source of disruption between preexposure and acquisition. Experiment 3 consisted of three groups (see Table 2), one in which the masking task during the preexposure phase was continued in the acquisition phase and two in which the masking task was modified between the two phases. As in the previous experiments, during the preexposure phase, all groups received A-O1 and B-O2 pairings. Group Same also received A-O1 and B-O2 pairings during the acquisition phase. For group NewCues, A and B were replaced by two new cues, C and D, respectively (i.e., C-O1 and D-O2 trials were given during acquisition). For group Reversal, the same masking task cues and outcomes as during preexposure were presented during the acquisition phase, but their relationship was reversed (i.e., A-O2 and B-O1). Thus, the novel stimulation between phases in this experiment took the form of a change in the masking task. If these manipulations have a similar impact on LI as interpolating a retention interval (Experiment 2), the results of Experiment 3 would extend the range of events known to attenuate LI in human predictive learning. Such an extension will facilitate assessment of current models of learning that attempt to account for LI (see General discussion). Briefly, if manipulations as diverse as interpolating a retention interval (Experiment 2) or introducing changes in the masking task cues (Experiment 3) between preexposure and acquisition produce the same effect on LI (i.e., attenuation of LI), then the range of models capable of explaining the results of both Experiments 2 and 3 will be importantly narrowed.

### *Method*

#### *Participants and apparatus*

The apparatus was identical to that of Experiment 1. The participants were 53 students [4 men and 49 women, with a mean age of 18.58 years (SEM = 0.22)] from the

University of Seville. Participants were assigned to one of three groups, resulting in 18 participants each in groups Same and Reversal, and 17 in group NewCues.

### *Design and procedure*

Unless otherwise noted, the procedural details were identical to those of Experiments 1 and 2. Table 2 summarizes the design of Experiment 3. For Group Same, the masking task cues (A and B) and target task cues (X and Y) were identical to those of group NoDelay in Experiment 2. For groups NewCues and Reversal, the target cue treatment was identical to that of group Same, whereas the masking task differed. Specifically, groups NewCues and Reversal were given, like group Same, 10 A-O1 and 10 B-O2 trials during the preexposure phase. However, whereas group Same was given 5 A-O1 and 5 B-O2 trials during acquisition, group NewCues received 5 C-O1 and 5 D-O2 trials and group Reversal received 5 A-O2 and 5 B-O1 trials. Because group NewCues was given training with four different masking task cues, two new cues were introduced (C and D). These new stimuli consisted of purple and brown colored lights on the spy-radio, which necessitated a new counterbalancing of the masking task cues. Cues A and C were blue and purple colored light (counterbalanced), whereas cues B and D were yellow and brown colored lights (counterbalanced).

### *Pre-analysis treatment of the data*

The same participant selection criterion as in Experiments 1 and 2 was used in the present experiment. However, this criterion could not be applied to the last training trial with cues A and B due to the different masking task cues among groups during the acquisition phase (see Table 2). Consequently, the selection criterion was applied to the last trial with cues A and B during the preexposure phase. On this basis, three participants, all from group Reversal, were eliminated from further data analysis.

### *Results and discussion*

#### *Masking task cues*

Fig. 4 depicts responding to the masking task cues. As can be seen, responding to cues A and B in group Same proceeded as in the previous experiments during the preexposure phase (Trials P1–P10) and the acquisition phase (A1–A5). Group NewCues also learned the discrimination between A and B during the preexposure phase. However, as would be expected, responding to the new cues (C and D) during acquisition, was reduced as compared to A and B in the Same group, particularly on Trial A1, after which responding to C was stronger than to D. Finally, group Reversal rapidly learned the change in the new relationship between the masking task cues and the outcomes. During the acquisition phase, group Reversal's responses to cue A progressively decreased on each A-O2 trial, a decrease that was accompanied by an increase in responding to cue B on each B-O1 trial. These impressions were confirmed by the following analyses.

A 3 (Group: Same vs. NewCues vs. Reversal)  $\times$  2 (Cue: A or C vs. B or D)  $\times$  15 (Trial) ANOVA on the mean number of responses yielded main effects of cue,  $F(1, 47) = 243.34, p < .001$ , and trials,  $F(14, 658) = 10.17, p < .001$ , but not of Group,  $p > .10$ .

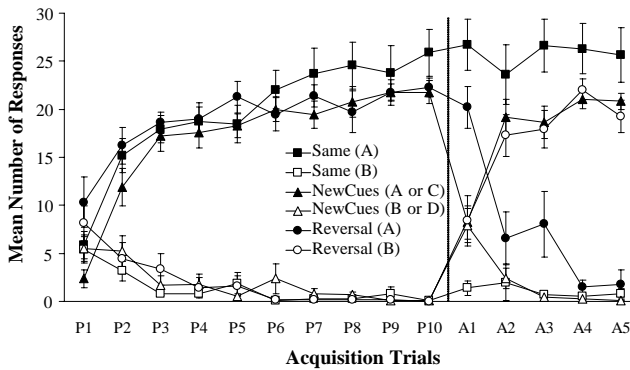


Fig. 4. Mean number of responses to the masking task cues, A, B, C, and D, during preexposure and acquisition in Experiment 3. Trial numbers preceded by 'P' and 'A' represent preexposure and acquisition trials, respectively. The vertical line separates preexposure trials from acquisition trials. Error bars depict standard error of the means.

All of the interactions were significant: Group  $\times$  Cue,  $F(2, 47) = 13.82$ ,  $p < .001$ , Group  $\times$  Trial,  $F(28, 658) = 2.51$ ,  $p < .001$ , Cue  $\times$  Trials,  $F(14, 658) = 37.58$ ,  $p < .001$ , and Group  $\times$  Cue  $\times$  Trial,  $F(28, 658) = 29.58$ ,  $p < .001$ . In summary, the discrimination between the masking task cues was learned and maintained throughout training in group Same. In group NewCues, the A–B and C–D discriminations were learned within a trial or two. In group Reversal, appropriate discriminative responding for the reversed contingencies was achieved after three trials. Thus, the masking task manipulations produced the expected effects on responding to the masking task cues.

#### Target task cues

The central results are depicted in Fig. 5. As can be seen, LI was obtained in group Same, but not in groups NewCues and Reversal. These impressions were supported by a 3 (Group: Same vs. NewCues vs. Reversal)  $\times$  2 (Cue: X vs. Y)  $\times$  5 (Trial) ANOVA on the mean number of responses, which yielded main effects of cue,  $F(1, 47) = 4.55$ ,  $p < .05$ , and trial,  $F(4, 188) = 48.50$ ,  $p < .001$ . All of the interactions also were significant: Group  $\times$  Cue,  $F(2, 47) = 6.76$ ,  $p < .005$ , Group  $\times$  Trial,  $F(8, 188) = 2.05$ ,  $p < .05$ , Cue  $\times$  Trial,  $F(4, 188) = 6.27$ ,  $p < .001$ , and, most importantly, Group  $\times$  Cue  $\times$  Trial,  $F(8, 188) = 4.64$ ,  $p < .001$ . Post hoc comparisons were made of responding to X and Y in each group. In group Same, responding to X was weaker than responding to Y on Trial A2, evidencing LI. In contrast, for groups NewCues and Reversal, there was no significant difference between responding to cues X and Y on any trial. Moreover, planned comparisons showed that the difference between the number of responses to X and Y on Trial A2 was higher in group Same relative to both group NewCues,  $F(1, 47) = 12.62$ ,  $p < .001$ , and group Reversal,  $F(1, 47) = 14.36$ ,  $p < .001$ . Also, the difference in responding to X and Y on Trial A2 was comparable in groups NewCues and Reversal ( $p > .72$ ). Thus, LI was comparably attenuated in groups NewCues and Reversal, and it is clear from Fig. 5 that these groups did not differ from one another. If the present changes in the masking task are regarded as a

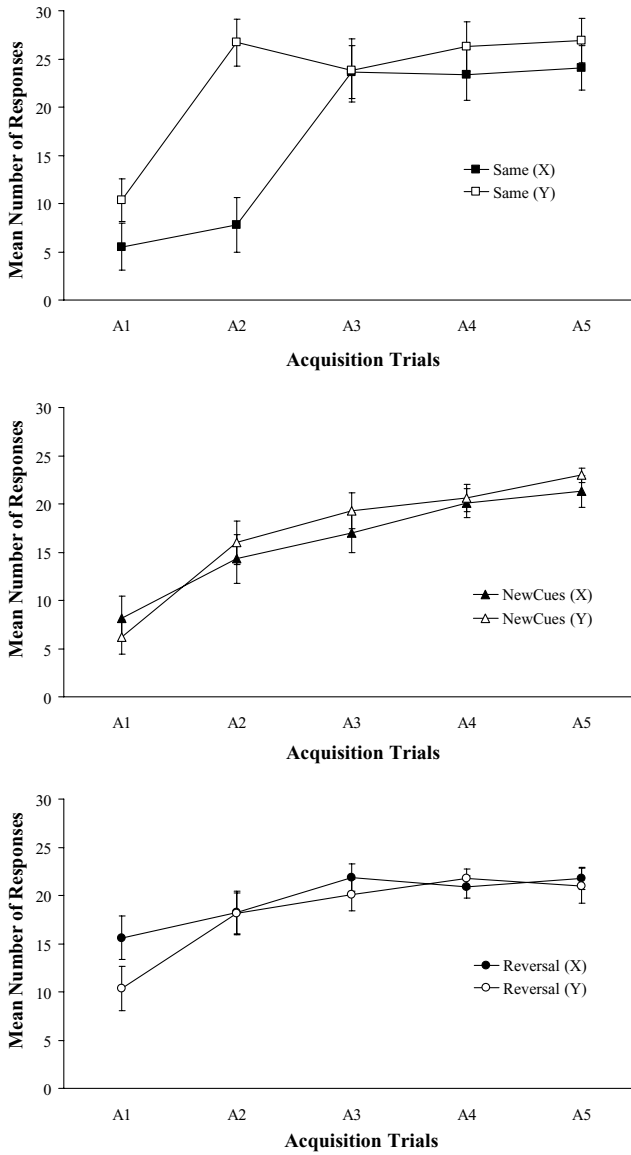


Fig. 5. Mean number of responses to the target cues, X and Y, during acquisition in Experiment 3. The top, middle, and bottom panels depict responding to both cues in groups Same, NewCues, and Reversal, respectively. Although only acquisition trials are depicted, trial numbers are preceded by 'A' (i.e., acquisition trials) for the sake of clarity. Error bars depict standard error of the means.

form of novel stimulation between preexposure and acquisition, then the present results are compatible with those in the animal conditioning literature that show that LI can be attenuated by the presentation of a novel stimulus between acquisition and testing (e.g., Escobar et al., in press; Lantz, 1973; Rudy et al., 1977).

Experiment 3 also provides insight concerning the potential influence of our use of a within-subject design for the study of LI in the present series of experiments. As the presentation of new masking task cues in group NewCues proved effective in attenuating LI, the presentation of a novel target cue, Y, during acquisition might also have partially alleviated cue X from the effect of its preexposure, thereby attenuating LI. The fact that LI was observed in this series of experiments does not preclude the possibility that stronger LI could have been found if a between-group design had been used.

## General discussion

The present experiments provided evidence of LI in a human predictive learning within-subject preparation. More importantly, Experiments 2 and 3 demonstrated that LI could be attenuated by certain experimental manipulations between preexposure and acquisition. Specifically, in Experiment 2, LI was decreased when a short retention interval (5 min) was interpolated between preexposure and acquisition, regardless of whether participants spent the interval in the experimental room (group Stay) or whether they left the experimental room during the delay (group Reseat). In Experiment 3, LI was attenuated by either replacing the masking task cues presented during the preexposure phase with new cues during the acquisition phase (group NewCues) or by reversing the relations between the masking task cues and outcomes between the preexposure and acquisition phases (group Reversal).

Overall, the results of Experiments 2 and 3 suggest that the LI effect is vulnerable to several different kinds of manipulations, all of them relatively unrelated to the target cues. These findings add to the other evidence in the human learning literature showing attenuation of LI by manipulations between preexposure and acquisition, such as presenting instructions to participants during a relatively long delay (e.g., Escobar et al., 2003) or giving acquisition training in a context different from that of preexposure (e.g., Gray et al., 2001; Zalstein-Orda & Lubow, 1995). These results are also consistent with findings from the animal conditioning literature that demonstrate that LI can be weakened by interpolating a retention interval (e.g., Hall & Minor, 1984; Rosas & Bouton, 1997; Wagner, 1979; Westbrook et al., 1981), switching contexts (e.g., Hall & Channell, 1985, 1986; Lovibond et al., 1984; Westbrook et al., 2000), or presenting novel stimulation (e.g., Escobar et al., *in press*; Lantz, 1973; Rudy et al., 1977) between preexposure and acquisition.

Because the present experiments, as well as those mentioned above, found attenuation of LI due to the occurrence of a variety of different types of events between preexposure and acquisition, one might ask what, if anything, do these events have in common that permits them to weaken LI. The answer to this question has important implications for theories of LI, and consequently for learning theories in general. Current theories of associative learning have offered divergent explanations of LI, mostly based on LI resulting from an acquisition failure (e.g., Lubow et al., 1981; Mackintosh, 1975; Pearce & Hall, 1980; Wagner, 1981), or alternatively, as resulting from either a retrieval or expression failure (Bouton, 1993; Miller & Matzel, 1988).

Among the acquisition-focused theories of LI, different mechanisms have been posited as responsible for the preexposed cue being impaired in acquiring an association with the outcome during cue–outcome pairings. Lubow et al.’s (1981) Conditioned Attention Theory (CAT; see also Lubow, 1989), together with the models of Mackintosh (1975) and Pearce and Hall (1980), explain LI as due to a failure to attend to the preexposed cue during cue–outcome pairings. However, these models diverge in the specific mechanism that is assumed responsible for LI. In CAT, the attentional response that is usually elicited by a new cue (e.g., orienting response) is assumed to wane over the course of preexposure due to the cue being followed by no outcome. In other words, during preexposure participants learn to ignore the cue. Because the attentional response is assumed to mediate acquisition of the cue–outcome association, prior cue preexposure, when it occurs without consequence, results in impaired learning. In a similar vein, the Mackintosh and Pearce–Hall models propose that attention to the cue decreases over the course of preexposure. However, these latter theories do not consider attention as a response, but rather as an attribute of the cue jointly determined by the properties of the stimulus and the subject’s processing of the stimulus. More specifically, these theories assume that the cue’s associability, represented by the  $\alpha$  parameter, varies as a function of how reliable the cue predicts the outcome. In Mackintosh’s model, the cue’s associability varies as a direct function of how predictive it is of a significant outcome. Thus, in this model, cue preexposure results in decreased cue associability due to the participant’s learning that the cue is a predictor of no outcome. By contrast, in the Pearce–Hall model, the associability decreases as the cue becomes a good predictor of any outcome. Because this model views the absence of the outcome as an outcome itself (Konorski, 1967), cue preexposure results in decreased associability due to the cue becoming a reliable predictor of no outcome.

Wagner’s (1981) SOP model also explains LI as a failure to learn the association between the preexposed cue and the outcome as arising from an attention failure. However, in this model, the processing of a preexposed cue within short-term memory (SOP’s A1 state) is impaired due to its being primed by the preexposure context into reference memory (SOP’s A2 state). Specifically, for SOP, cue preexposure results in the formation of a context–cue association. Based on this association, the context will associatively prime the cue into A2, which results in the cue receiving less processing in A1 (i.e., decreased attention). Because only the stimuli that are conjointly activated into the A1 state form an excitatory association, the weakened A1 processing received by the preexposed cue (due to its being activated into A2 by the context) will result in impaired learning of the cue–outcome association. Therefore, although Wagner’s SOP model is not an attentional model by nature,<sup>4</sup> it converges with the attentional models of learning (e.g., Lubow et al., 1981;

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<sup>4</sup> In Wagner’s (1981) SOP model, representational nodes activated into the A1 and A2 states are assumed to be in the participant’s focal attention and peripheral attention, respectively. Cue preexposure results in the cue receiving less processing in the participant’s focal attention (A1). In this sense, SOP’s view of LI is quite similar to that of attentional theories (e.g., Lubow et al., 1981; Mackintosh, 1975; Pearce & Hall, 1980).

Mackintosh, 1975; Pearce & Hall, 1980) in viewing LI as representing a deficit in the subsequent associability of the preexposed stimulus in the context in which preexposure occurred.

In a different vein, Bouton's (1993) retrieval failure model proposes that LI is due to the cue-no outcome association, which is learned during preexposure, interfering with retrieval of the cue-outcome association learned during acquisition. That is, in Bouton's model cue preexposure does not impair learning, but impairs retrieval from memory of the cue-outcome association. Importantly, in this model retrieval of the cue-no outcome association depends on the context in which it was trained (but see Bouton, 1997, for a different view based on the contextual dependency of second-learned associations). Hence, according to Bouton, LI will maximally occur, when testing occurs in the same context in which the cue was preexposed.

Like Bouton's (1993) model, Miller and Matzel's (1988) comparator hypothesis views LI as a failure to express the cue-outcome association, rather than as an impaired acquisition of the target cue-outcome association. However, in the framework of the comparator hypothesis, LI is not assumed to occur due to a cue-no outcome association interfering with retrieval of the target association, but due to the cue-context association (in conjunction with the context-outcome association) interfering with retrieval of the cue-outcome association. The comparator hypothesis assumes that responding to the cue in the LI preparation depends on the status, at the time of testing, of three associations or links: (1) the cue-outcome association, (2) the cue-context association and, (3) the context-outcome association. Specifically, responding at the time of testing depends on a comparison between the direct activation of the outcome representation (i.e., the strength of the cue-outcome association) and the indirect activation of the outcome representation (i.e., the product of the strengths of the cue-context and context-outcome associations). According to the comparator hypothesis, LI occurs due to the strengthening of the cue-context association during preexposure resulting in strong indirect activation of the outcome representation at test.

With these models in mind, we can now return to our original question: What do the different manipulations that attenuate LI when applied between preexposure and acquisition (e.g., retention intervals, context changes, and novel stimulation) have in common? For one thing, all of the manipulations, while not altering the original target stimulus contingencies in preexposure or acquisition, require the subject to engage in new information processing. Although this might seem trivial, it is important to note that neither the Mackintosh (1975) nor the Pearce and Hall (1980) model can account for any of these effects. According to these models, LI results exclusively from the cue losing its associability during cue-alone presentations. Therefore, only those treatments that directly involve the cue should be able to influence the cue's associability (e.g., associability can be increased by pairing the cue with a non-target outcome before acquisition, thereby attenuating LI).

All of the aforementioned manipulations might also be viewed as producing a change of context (see Bouton, 1993, for a broad definition of context that includes physical and temporal attributes). Indeed, the attenuation of LI by administering

preexposure and acquisition treatments in different contexts (e.g., Gray et al., 2001; Hall & Minor, 1984; Rosas & Bouton, 1997; Wagner, 1979; Westbrook et al., 1981) is readily explained by Bouton (1993), Miller and Matzel (1988), and Wagner (1981). Specifically, in Bouton's model, the acquisition context, when different from the preexposure context, would be unable to retrieve the cue-no outcome association. Consequently, the cue-no outcome association could not interfere with retrieval of the cue-outcome association during acquisition. In Miller and Matzel's comparator hypothesis, a change of context between preexposure and acquisition would result in a weak association between the cue and the acquisition context relative to a no-context-change condition. Therefore, even though the acquisition context is equally paired with the outcome in both cases, if preexposure and acquisition occur in different contexts, the presentation of the cue at test would weakly activate the representation of the acquisition context relative to subjects which experienced preexposure and acquisition in the same context. Consequently, administering preexposure and acquisition treatments in different contexts should result in the cue at test retrieving a weak indirectly activated representation of the outcome and, as a result, in attenuation of LI. In Wagner's SOP, attenuated LI is expected due to the inability of the new acquisition context to prime the target cue into A2, which, in turn, would result in normal acquisition of the cue-outcome association. In summary, despite important differences, all of these models can explain the attenuated LI that is obtained when the preexposure and acquisition sessions are conducted in different contexts.

Problems with these models (Bouton, 1993; Miller & Matzel, 1988; Wagner, 1981) arise when one examines the effects of manipulations other than physical differences in preexposure and acquisition contexts. For example, because passage of time is viewed as a contextual change in Bouton's theory (also see Balsam, 1985), this model can readily explain the attenuation of LI produced by interpolating a retention interval between preexposure and acquisition (e.g., Escobar et al., 2003). However, Wagner's SOP and Miller and Matzel's comparator hypothesis provide no mechanism by which passage of time per se can attenuate LI. They can explain the impact of a retention interval on LI only when the interval is spent in the experimental context. In this case, context exposure in the absence of the cue should extinguish the context-cue association and, hence, result in the cue being released from LI. Although there is some evidence supporting this prediction (e.g., Escobar et al., 2003; Hall & Minor, 1984; Wagner, 1979; Westbrook et al., 1981), LI also has been attenuated when the retention interval did not involve continued context exposure (e.g., Rosas & Bouton, 1997). Moreover, our Experiment 2 found attenuation of LI not only in a group that spent the retention interval in the experimental rooms (group Stay), but also in a group in which the retention interval was spent outside the experimental rooms (group Reseat) and, therefore, for which extinction of the context-cue association cannot by itself account for attenuation of LI.

In a similar vein, to account for the observation that LI is attenuated by presenting novel stimuli during acquisition (e.g., Escobar et al., *in press*; Lantz, 1973; Rudy et al., 1977; group NewCues in the current Experiment 3), these models (Bouton, 1993; Miller & Matzel, 1988; Wagner, 1981) might assert that the presentation of new stimuli during acquisition is akin to conducting acquisition in a new context, as would

reversing the contingencies between the masking task cues and the outcome between preexposure and acquisition (group Reversal in Experiment 3).

Alternatively, the commonality of these manipulations may be that they all disrupt the transition between preexposure and acquisition treatments. In this view, differences between the preexposure and acquisition contexts are only relevant in that a contextual switch would disrupt an otherwise smooth transition between these two phases. Similarly, this transition might be disrupted by a retention interval, new stimuli, or even by reversing the relationship between the masking task cues and their outcomes. One consequence of a disruption in the transition between phases might be to restore the participants' attention to *all* the elements in the experimental task, including the preexposed cue. The view that attenuation of LI can be produced by the restoration of attention by the interpolation of a disruptive event is not new. In fact, it was formally predicted by Lubow et al.'s (1981, p. 14) CAT: "LI will be subject to the effects of external inhibition, i.e., will be disrupted by the introduction of an extraneous event following the  $S_1$ -alone presentations. The event may be a different stimulus, a response, an environmental change, etc. In terms of CAT, the presentation of the extraneous event will serve to restore attention to the presented stimulus and thus prevent establishment of inattention." This aspect of CAT is also supported by the disruptive effect of the retention interval on responding to cue A in both conditions Stay and Reseat (Experiment 2). The possibility that LI was attenuated by the retention interval producing external inhibition is consistent with the observed decrease in responding to cue A on its first presentation after the retention interval (i.e., Trial A1, see Fig. 2).

In conclusion, CAT (Lubow et al., 1981; see also Lubow, 1989) appears to provide a parsimonious and complete account of attenuation of LI by manipulations between preexposure and acquisition. However, this model still faces some difficulties. First, the model claims that presenting extraneous events between preexposure and acquisition can disrupt LI, but the disruptive potential of an extraneous event cannot be assessed a priori, but only by means of its impact on the LI effect. This lack of an external and independent measure of the disruptive potential of a given event leads to a circular notion of the event's disruptive potential for LI: LI can be attenuated by presenting a disruptive external event, but a given external event is certified to be disruptive as a function of its ability to attenuate LI. Second, CAT encounters difficulties in explaining the impact of some of the aforementioned manipulations when they are introduced between acquisition and testing. For example, CAT offers no account of the enhanced LI that is observed in three-phase preparations when a long delay is introduced between acquisition and test and that delay is spent in a context that is *different* from that of the other experimental phases (i.e., the super-LI effect, De la Casa & Lubow, 2000, 2002; Lubow & De la Casa, 2002; Stout et al., in press; Wheeler et al., 2004) nor recovery from LI produced by exposure to the US which facilitates subsequent retrieval of the target association (i.e., a reminder treatment; e.g., Kaspro, Catterson, Schachtman, & Miller, 1984). As simple and ubiquitous as the LI effect appears to be, considerably more research is required to achieve a unified theoretical account of the ever-increasing number of variables that appear to modulate it.

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