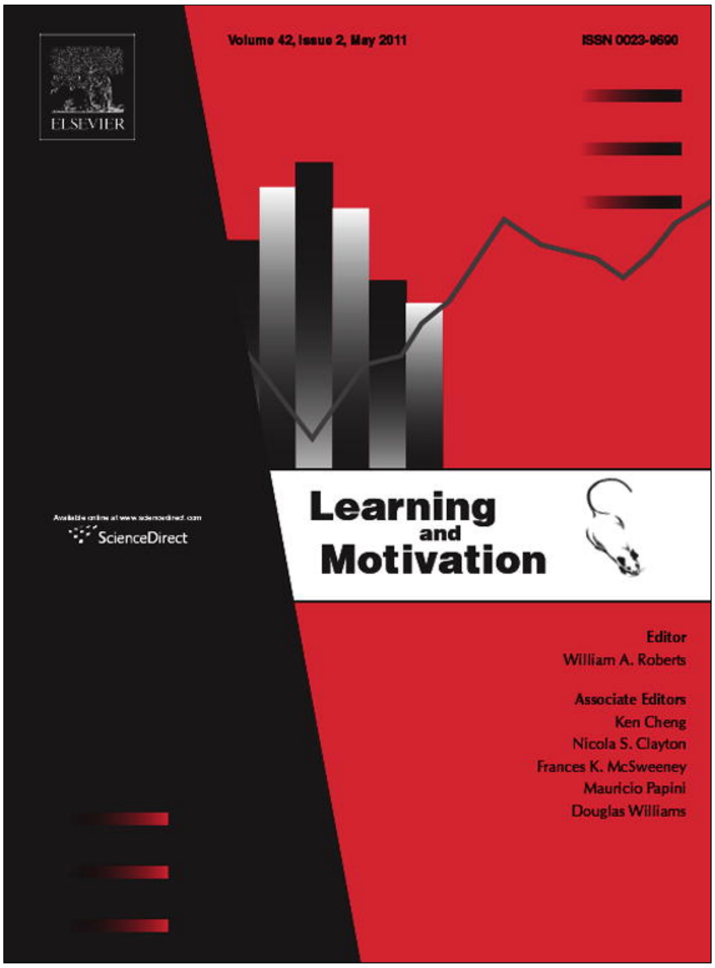
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Reinforced stimulus preexposure effects as a function of US intensity: Implications for understanding the Hall–Pearce effect

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ABSTRACT

Three conditioned suppression experiments examined the Hall–Pearce (1979) negative transfer effect in rats. Experiment 1 replicated the effect: CS-US_{weak} pairings retarded subsequent fear conditioning to the CS as a result of CS-US_{strong} pairings. The size of this retardation was less than that produced by non-reinforced CS presentations (latent inhibition). When the magnitude of the US_{weak} was reduced in Experiment 2, the Hall–Pearce effect was greater than latent inhibition. Experiment 3 confirmed the findings of the two previous experiments, and demonstrated that magnitude of the Hall–Pearce negative transfer effect is inversely related to the magnitude of the US_{weak}. From these findings it is suggested that the Hall–Pearce effect consists of a balance between a positive transfer of associative strength, and negative transfer based on CS- and US-preexposure effects.

In a conditioned suppression experiment by Hall and Pearce (1979), rats were given initial training in which a conditioned stimulus (CS) was paired with a relatively weak electric shock as the unconditioned stimulus (US_{weak}) and then a test phase where training continued, but the shock intensity was increased (US_{strong}). In the test phase these subjects learned—i.e., acquired the suppression to the CS—relatively slowly compared to control subjects that had experienced the CS for the first time during the phase of CS-US_{strong} training (see also, Ayres, Moore, & Vigorito, 1984; Hall & Pearce, 1982; Kasprow, Schachtman, & Miller, 1985; Kaye, Preston, Szabo, Druiff, & Mackintosh, 1987; Savastano, Yin, Barnet, and Miller, 1997; Schachtman, Channell, & Hall, 1987; Swartzentruber & Bouton, 1986; Young & Fanselow, 1992). This Hall–Pearce negative transfer effect has commonly been interpreted (e.g., Pearce & Hall, 1980; Wagner, 1981) as a variant of the latent inhibition effect—the observation that repeated nonreinforced preexposure to the to-be-CS retards subsequent conditioning (Lubow & Moore, 1959; see for reviews Hall, 1991; Lubow, 1989). From this interpretation, the retardation in conditioning that characterizes both phenomena reflects a loss of associability (or conditionability) by the CS.

Given this suggested parallel, direct comparison of the conventional latent inhibition effect and the Hall–Pearce effect is of interest, because it could help to understand the nature of the mechanism, or mechanisms, underlying changes in stimulus associability. All the studies that have addressed this comparison (Hall & Pearce, 1979; Kasprow et al., 1985; Schachtman et al., 1987; Swartzentruber & Bouton, 1986) have observed that learning of the CS-US_{strong} association was less retarded by previous CS-US_{weak} training (the Hall–Pearce condition) than by previous CS-alone training (the standard latent inhibition condition). This difference has been interpreted as showing that the introduction of the US_{weak} in the Hall–Pearce treatment attenuates in some way the loss of associability suffered by the CS experienced on its own (e.g., Lubow, 1989, p. 132; Wagner, 1981). This difference is also open to a theoretically much less interesting interpretation. The CS will acquire some amount of associative strength during the initial CS-US_{weak} pairings, that will necessarily contribute to the further emergence

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Table 1
Experimental designs.

Experiment 1		Experiment 2		Experiment 3	
Phase 1	Phase 2	Phase 1	Phase 2	Phase 1	Phase 2
T-sh group		T-sh group		T-sh1 group	
$T \rightarrow US_{weak1}$	$T \rightarrow US_{strong}$	$T \rightarrow US_{weak2}$	$T \rightarrow US_{strong}$	$T \rightarrow US_{weak1}$	$T \rightarrow US_{strong}$
T group		T group		T-sh2 group	
T → nothing	$T \rightarrow US_{strong}$	T → nothing	$T \rightarrow US_{strong}$	$T \rightarrow US_{weak2}$	$T \rightarrow US_{strong}$
L-sh group		L-sh group		T group	
$L \rightarrow US_{weak1}$	$T \rightarrow US_{strong}$	$L \rightarrow US_{weak2}$	$T \rightarrow US_{strong}$	T → nothing	$T \rightarrow US_{strong}$
		L group			
		L → nothing	$T \rightarrow US_{strong}$		

Note: T and L = tone and light CSs, respectively; US_{weak1} = electric footshock of .4 mA and 0.2 s; US_{weak2} = footshock of .25 mA and 0.2 s; US_{strong} = footshock of .8 mA and 0.5 s.

of the conditioned response (CR) during the subsequent CS-US_{strong} training. This positive transfer will inherently tend to underestimate the actual magnitude of the loss of associability (or any other source of negative transfer) that the Hall–Pearce treatment generates.

The present study investigated an implication of this analysis. Observation of the actual magnitude of the Hall–Pearce negative transfer effect should be facilitated by arranging training conditions that limit the acquisition of associative strength by the CS during the CS-US_{weak} training. The first experiment provided a replication of the effect with our procedures, and Experiments 2 and 3 were designed to reduce the amount of conditioning that could accrue to the CS during US_{weak} pairings by decreasing the magnitude of the shock employed as the US_{weak}. In theory, that manipulation should reduce the amount of maximum associative strength acquired by the CS during Phase 1 (e.g., Kamin, 1969; Rescorla & Wagner, 1972), but still reduce the CSs associability (e.g., Pearce & Hall, 1980). The question of interest was whether under these conditions the magnitude of the Hall–Pearce effect would be still less than that of the latent inhibition effect.

Experiment 1

The goal of Experiment 1 was to provide an initial demonstration of the Hall–Pearce effect, compared to latent inhibition produced by exposure to the CS alone. The design and parameters (see Table 1) were directly modelled on the original study by Hall and Pearce (1979; Experiment 2). It consisted of two phases. All subjects, three groups of rats, were given pairings of a tone CS with a relatively strong footshock US in Phase 2. Groups differed in the prior training they received during Phase 1. The first group, Group T-sh, received presentations of the tone followed by a weaker shock than that used in Phase 2. The second, Group T, provided a latent inhibition manipulation where the tone was presented without shock. And finally, Group L-sh received presentations of a non-target stimulus (light) followed by the weak shock.

Method

Subjects

The subjects were 24 male Wistar rats with a mean ad lib weight of 415 g (range: 345–540 g). They had served previously in an experiment using flavor aversion conditioning techniques, but they were naive to the present stimuli, apparatus, and procedures. The rats were housed in pairs with continuous access to water, and were maintained at 80% of their ad lib weights by a schedule of controlled feeding. The colony room was artificially lit from 8 a.m. to 8 p.m. each day; the experimental procedures occurred in the afternoon phase of the light cycle.

Apparatus

Eight Skinner boxes (Coulbourn Instruments) were used. The ceiling and front and rear walls of each box were made from aluminum, whereas the two side walls were made from transparent plastic. The floor of the box was composed of stainless steel rods 6 mm in diameter and spaced 1.5 cm apart center-to-center. The floor could be electrified by an AC shock generator. Each box was equipped with a response lever located on the front wall, 6 cm above the floor. The food tray was 2 cm from the floor in the center of the front wall, situated to the right of the lever, and was connected via a plastic tube to an external 45-mg pellet dispenser. Each box was housed in a sound-attenuated cubicle equipped with a fan that supplied a background noise of 40 dB. Two different stimuli were used as CSs. The first was the illumination supplied by the simultaneous lighting of three bulbs (28 V and 0.04 A), aligned horizontally 11 cm over the response lever. This stimulus will be referred to simply as the light (L). The second CS was a continuous tone of 4.5 kHz and 85 dB, generated by a loud speaker located 6 cm over the bulbs. Both stimuli had a duration of 90 s.

Procedure

The design of the experiment is presented in Table 1. All experimental sessions were conducted in darkness and lasted 60 min, except for the three sessions of Phase 2, which lasted 40 min.

Initially, the animals received shaping sessions. In each, food pellets were delivered on a variable-time (VT) 60-s schedule while lever press responses were continuously reinforced. Each rat finished magazine training when it made 100 lever press responses. Subjects then received 12 sessions of lever press response training (baseline). The lever press response was reinforced with one food pellet on a variable interval (VI) 30-s schedule during the first session. In the remaining sessions, reinforcement was delivered according to a VI 60-s schedule. The following experimental sessions were conducted on the baseline of the lever press response.

Rats were randomly assigned to one of three equal-sized groups (Group T-sh, Group T, and Group L-sh) before starting Phase 1. Phase 1 consisted of 11 sessions, each containing 6 trials. The inter-trial interval (ITI) was variable around a mean duration of 360 s. For Group T-sh, in each trial the tone was followed immediately by the weak 0.2-s electric shock (0.4 mA). Group T was treated in the same way except that the shocks were omitted. For Group L-sh, in each trial the light was followed by the weak shock. All subjects were treated identically in Phase 2. In each of three sessions, all groups received 2 trials in which the tone was followed by a stronger electric shock of 0.8 mA for 0.5 s. The first trial began 360 s and the second trial 1560 s after the start of the session.

Lever press responses were recorded and standard suppression ratios to the CS were calculated in accordance with the $X/(X+Y)$ formula, where X is the number of lever press responses during the CS, and Y represents the number of lever press responses during a period of equal duration immediately prior to the onset of the CS.

Results and discussion

The left panel of Fig. 1 presents mean suppression ratios for each group during the 11 sessions of Phase 1. It is clear that the tone did not command any suppression in Group T. However, pairing the light or the tone with the US_{weak} (Groups T-sh and L-sh) produced some suppression to either CS, with slightly stronger suppression to the light than to the tone suggesting that the light was a more salient (e.g., Kamin, 1969) CS than the tone. An analysis of variance (ANOVA) with Group and Session as the variables was conducted on these data and confirmed these impressions. It revealed significant effects of Group, $F(2, 21) = 11.21$, and of Session, $F(10, 210) = 5.32$ (here and elsewhere a significance level of $p < .05$ was adopted). The interaction between these variables was not significant, $F(20, 210) = 1.26$. Pairwise comparisons using Duncan tests showed that Groups T-sh and L-sh suppressed more than Group T, and that Group L-sh suppressed more than Group T-sh.

Planned comparisons were conducted in order to confirm the effectiveness of the conditioning procedure. By Session 7, Groups T-sh and L-sh suppressed more than on Session 1, $ts(7) > 3.10$. After Session 7, Groups T-sh and L-sh showed a post asymptotic decline in suppression. Both groups suppressed less on Session 11 than they did on Session 7, $ts(7) > 2.62$. This habituation in the conditioned responding after extended CS-US pairings has been observed in previous studies using the same design and similar parameters to those used here (e.g., Ayres et al., 1984; Hall & Pearce, 1979; Savastano et al., 1997). These results indicate that subjects in Groups T-sh and L-sh learned the CS-US_{weak} association.

The treatment administered in Phase 1 did not differentially influence the groups' baseline response rates. Thus on the last day of this phase, Group T-sh had a mean response rate of 20.06 responses per minute; Group T, 21.29 responses per minute; and Group L-sh, 19.13 responses per minute. These means did not differ significantly ($F < 1$). Over all 3 days of Phase 2, the baseline response rates were 17.67, 16.61, and 14.22 responses per minute for groups T-sh, T, and L-sh, respectively. These means did not differ significantly ($F < 1$).

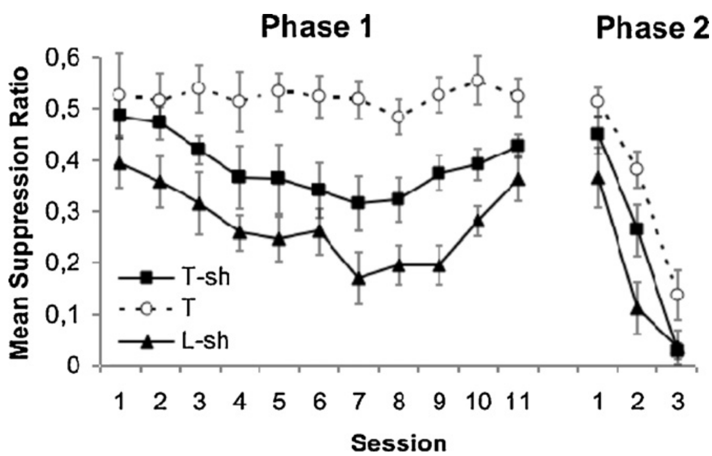

Fig. 1. Experiment 1: Mean suppression ratio to the CSs during Phases 1 and 2. Training conditions are illustrated in Table 1 and described in the text. Vertical bars represent the standard errors of the means (SEMs).

The right panel of Fig. 1 presents mean suppression ratios for each group during the 3 sessions of Phase 2. It is apparent from the figure that all three groups acquired suppression, but that the groups preexposed to the tone did so less readily than Group L-sh, for which the tone was a new stimulus at the start of this Phase. Although retarded with respect to Group L-sh, Group T-sh acquired suppression more readily than did Group T. An ANOVA with Group and Session as the variables was conducted on these data and confirmed all these impressions. There were significant effects of Group, $F(2, 21) = 11.44$, and of Session, $F(2, 42) = 112.36$. The interaction between these variables was not significant, $F(4, 42) = 1.99$. Pairwise comparisons using Duncan tests showed that each group differed from each of the other groups.

The present results provide a replication of those found by Hall and Pearce (1979; Experiment 2). The slow acquisition during Phase 2 observed after non-reinforced preexposure to the tone (Group T) constitutes an example of the well established phenomenon of latent inhibition. The parallel, but less severe, retardation observed after reinforced preexposure to the tone (Group T-sh) is an instance of the Hall–Pearce effect. An obvious explanation for the difference between Groups T-sh and T is that tone-US_{weak} pairings caused a positive transfer of associative strength in the former group. The conditioned suppression showed by Group T-sh in Phase 1 supports the possibility of that positive transfer. The next experiment tested an implication of this analysis. Reducing the magnitude of the US_{weak} should reduce the amount of maximum associative strength able to be acquired by the CS during Phase 1 (e.g., Kamin, 1969; Rescorla & Wagner, 1972), and thus limit the contribution of positive transfer in Phase 2. If so, a stronger Hall–Pearce effect should be observed under those conditions.

Experiment 2

The design of Experiment 2 (see Table 1) was identical to that of Experiment 1, with two exceptions. First, a further control condition was included (a group receiving non-reinforced presentations of the light in Phase 1) in order to complete a 2×2 factorial design, with Stimulus (tone vs. light as the CS in Phase 1) and Conditioning (reinforced vs. non-reinforced trials in Phase 1) as factors. The second change introduced was a reduction of the magnitude of the shock used as the US_{weak} in Phase 1: specifically, 0.25 mA for 0.2 s rather than 0.4 mA for 0.2 s used in Experiment 1.

Method

Subjects

The subjects were 32 male Wistar rats with a mean ad lib weight of 520 g (range: 440–610 g). They had served previously in an experiment using flavor aversion conditioning techniques, but they were naive to the present stimuli, apparatus, and procedures. They were maintained on a schedule of food deprivation as in Experiment 1.

Apparatus and procedure

The same apparatus used in the first experiment was used here. Rats were randomly assigned to one of four equal-sized groups (Groups T-sh, T, L-sh, and L) before starting Phase 1.The procedure for Groups T-sh, T, and L-sh, was the same as that described for Experiment 1, except that, for Groups T-sh and L-sh, the US_{weak} in Phase 1 was an electric shock of 0.25 mA for 0.2 s. The procedure for Group L was the same as that of Group L-sh, with the exception that the shock presentations were omitted during Phase 1. Details not specified here were the same as those described for Experiment 1.

Results and discussion

The left panel of Fig. 2 presents mean suppression ratios for each group during the 11 sessions of Phase 1. First, it is worth noting that levels of suppression shown by Groups T-sh and L-sh were weaker than those observed in Experiment 1. This

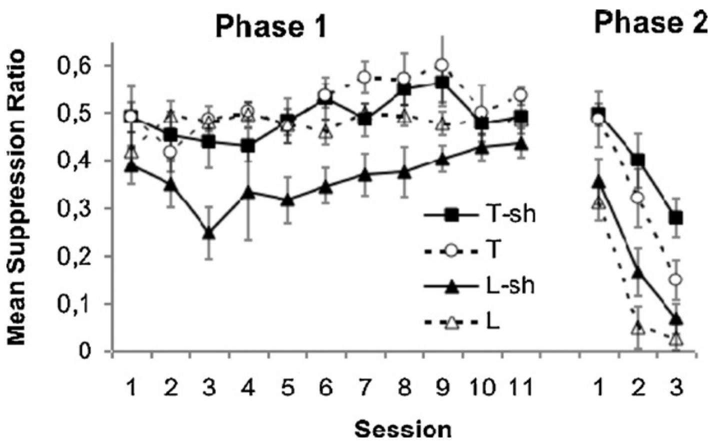

Fig. 2. Experiment 2: Mean suppression ratio to the CSs during Phases 1 and 2. Training conditions are illustrated in Table 1 and described in the text. Vertical bars represent the standard errors of the means (SEMs).

suggests that the reduction of the magnitude of the US_{weak} introduced in the present experiment was effective in limiting conditioning to the CSs. Also, as in Experiment 1, conditioning to the light (Group L-sh) produced stronger suppression than conditioning to the tone (Group T-sh), which supports the notion that the light was a more salient stimulus than the tone. Introduction of the US_{weak} had an effect when the CS was the light (Group L-sh showed suppression to the light whereas Group L did not) but not when the CS was the tone. Contrary to what was observed in Experiment 1, Group T-sh showed an absence of suppression to the tone, similar to that shown by Group T. A mixed three-way ANOVA with Stimulus (tone vs. light), Conditioning (reinforced vs. non-reinforced trials on Phase 1), and Session as the variables confirmed all these impressions. It revealed main effects of Stimulus, $F(1, 28) = 18.76$, Conditioning $F(1, 28) = 13.82$, and Session, $F(10, 280) = 2.15$. The Stimulus × Conditioning interaction also was significant, $F(1, 28) = 5.49$. None of the interactions involving Session was significant, $Fs(10, 280) < 1$. In order to explore the source of the significant Stimulus × Conditioning interaction, a simple main effects analysis was conducted. It revealed a Conditioning effect between the groups preexposed to the light, $F(1, 14) = 16.65$, but not between the groups preexposed to the tone, $F(1, 14) = 1.05$. Furthermore, a significant effect of Stimulus was found for groups which received conditioning, $F(1, 14) = 14.99$, but not for groups which received nonreinforced preexposure, $F(1, 14) = 3.79$, $p = 0.07$.

Planned comparisons were conducted in order to confirm the effectiveness of the conditioning procedure. It was found that Group L-sh acquired the suppression to the light during the three first sessions, suppressing more on Session 3 than on Session 1, $t(7) = 3.20$. After Session 3, this group showed a post asymptotic decline in suppression, suppressing less on Session 11 than it did on Session 3, $t(7) = -2.61$. Phase 1 training did not affect the level of suppression shown by Groups T-sh, T, and L.

These results indicate that subjects in Group L-sh learned the light-US_{weak} association. However, it is not clear whether or not the tone-US_{weak} association was established in Group T-sh. Our interpretation is that this association was indeed learned. The conditioned suppression shown by Group L-sh relative to Group L suggests that the weak shock employed in the present experiment worked as an effective US. It is likely, however, that the smaller amount of associative strength resulting from pairing a less salient CS (the tone vs. the light) with the weak US was not enough to yield conditioning performance (i.e., suppression).

Training in Phase 1 did not differentially influence the groups' baseline response rates. On the last day of this phase, Group T-sh had a mean response rate of 23.99 responses per minute; Group T, 28.05 responses per minute; Group L-sh, 20.25 responses per minute; and Group L, 24.85 responses per minute. These scores did not differ significantly, $F < 1$. Over all 3 days of Phase 2, the rates were 16.62, 21.81, 14.22, and 15.19 responses per minute for groups T-sh, T, L-sh, and L, respectively. These scores did not differ significantly, $F = 1.05$.

The right panel of Fig. 2 presents mean suppression ratios for each group during the 3 sessions of Phase 2. It is apparent from the figure that all four groups acquired suppression, but that the groups preexposed to the tone did so less readily than those preexposed to the light. Importantly, Group T-sh acquired suppression less readily than Group T. That is, rather than being attenuated relative to latent inhibition as in Experiment 1, retardation seems to have been enhanced by the Hall–Pearce treatment. A similar detrimental effect of the reinforced preexposure was observed in the groups preexposed to the light, with Group L-sh acquiring suppression slightly less readily than Group L. This suggests a US-preexposure effect (e.g., Randich & LoLordo, 1979), with extended preexposure to the US_{weak} in Phase 1 reducing the effectiveness of the US_{strong} as a reinforcer in Phase 2. An ANOVA with Stimulus (tone vs. light as the CS in Phase 1), Conditioning (reinforced vs. nonreinforced trials in Phase 1) and Session as the variables, conducted on these data, confirmed this description. It revealed significant effects of Stimulus, $F(1, 28) = 31.74$, Conditioning, $F(1, 28) = 4.28$, and Session, $F(2, 56) = 83.56$. None of the possible interactions was found to be significant, $Fs < 2.83$; $ps > 0.06$.

A series of planned comparisons were conducted in order to establish, first, that the present conditions resulted in a conventional Hall–Pearce effect (with Group T-sh acquiring suppression more slowly than Group L-sh); and second, that the Hall–Pearce condition (Group T-sh) resulted in more negative transfer than the latent inhibition condition (Group T). Both impressions were confirmed. Group T-sh suppressed less than Group L-sh on sessions 1, 2, and 3, $ts(14) > 3.04$, and less than Group T on session 3, $t(14) = 2.31$.

These results support the hypothesis that motivated the present experiment. It seems that limiting positive transfer of associative strength produced a stronger negative transfer effect. This effect seems to be bigger than the negative transfer produced by non-reinforced preexposure (latent inhibition condition). Also of importance is the observation that reinforced preexposure (with both the light and tone CSs) retarded learning of the tone-US_{strong} association with respect to nonreinforced preexposure. This can be taken as an instance of the US-preexposure effect, with extended preexposure to the US_{weak} reducing the effectiveness of the US_{strong} as a reinforcer (e.g., Randich & LoLordo, 1979). From this analysis, the Hall–Pearce treatment involves two additive sources of negative transfer: CS- and US-preexposure effects. Before pursuing these implications in the General Discussion, Experiment 3 directly compared the negative transfer effects of using the two different weak USs employed in Experiments 1 and 2.

Experiment 3

The design consisted of three groups (see Table 1). Groups T-sh1 and T-sh2, were identical to the Hall–Pearce effect conditions used in Experiments 1 and 2, respectively. That is, these two groups only differed in the magnitude of the US_{weak} used in Phase 1. Group T-sh1 received the weak shock from Experiment 1, and Group T-sh2 received that from Experiment

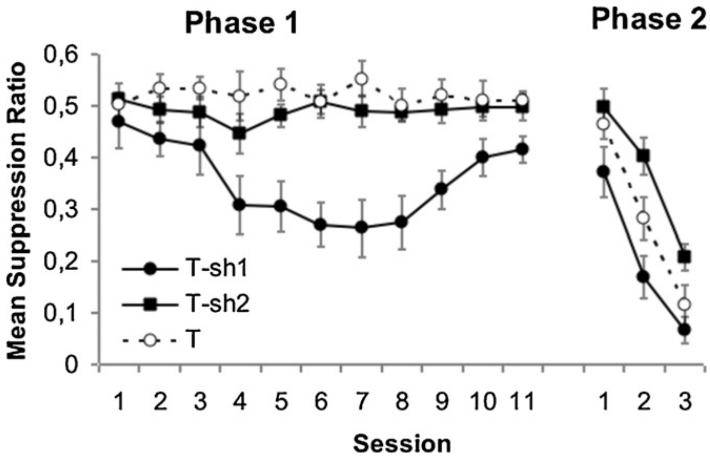

Fig. 3. Experiment 3: Mean suppression ratio to the tone CS during Phases 1 and 2. Training conditions are illustrated in Table 1 and described in the text. Vertical bars represent the standard errors of the means (SEMs).

2. The standard latent inhibition condition used in the previous experiments, Group T, was also included. We expected to observe slower acquisition (stronger negative transfer) in Group T-sh 2 than in Group T-sh1. In addition, relative to the latent inhibition control we expected to replicate the results of the previous experiments, finding slower acquisition in Group T-sh2 than Group T, and faster acquisition of Group T-sh1 than Group T.

Method

Subjects

The subjects were 24 male Wistar rats with a mean ad lib weight of 418 g (range: 355–490 g). They had served previously in an experiment using flavor aversion conditioning techniques, but they were naive to the present stimuli and procedures. They were maintained on a schedule of food deprivation as in Experiment 1.

Apparatus and procedure

The same apparatus used in the previous experiments was used here. After lever pressing had been established, rats were randomly assigned to one of three equal-sized groups (Groups T-sh1, T-sh2, and T). For Group T-sh1, the US_{weak} was that used in Experiment 1, an electric shock of 0.4 mA for 0.2 s; and for Group T-sh2, the US_{weak} was that used in Experiment 2, an electric shock of 0.25 mA for 0.2 s. Details not specified here were the same as those described for Experiment 1.

Results and discussion

The left panel of Fig. 3 presents mean suppression ratios for each group during the 11 sessions of Phase 1. Conditioning trials with the strongest US_{weak} in Group T-sh1 produced some suppression to the tone. Both Groups T-sh2 and T showed an absence of suppression. An ANOVA with Group and Session as the variables was conducted on these data and confirmed this description. It revealed significant effects of Group, $F(2, 21) = 14.70$, and of Session, $F(10, 210) = 2.54$. The interaction between these variables was also significant, $F(20, 210) = 1.93$. Simple main effects analyses then revealed a significant difference among the groups on Sessions 4, 5, 6, 7, 8, 9, and 11, $Fs(2, 21) > 3.87$. Pairwise comparisons for these sessions using Duncan tests showed that Group T-sh1 suppressed more than Groups T-sh2 and T. Also, the effect of session was found to be significant in Group T-sh1, $F(10, 70) = 3.01$, but not in Groups T-sh2 and T, $Fs(10, 70) < 1$. By Session 7, Group T-sh1 suppressed more than on Session 1, $t(7) = 2.25$. After Session 7, this group showed a post asymptotic decline in suppression, responding less on Session 11 than it did on Session 7, $t(7) = -2.43$. These results replicate those observed in the two previous experiments.

Phase 1 did not differentially influence the groups' baseline response rates. On the last day of this phase, Group T-sh1 had a mean response rate of 25.38 responses per minute; Group T-sh2, 23.99 responses per minute; and Group T, 31.18 responses per minute. These scores did not differ significantly ($F < 1$). Baseline rates of responding were maintained during Phase 2. Over all 3 days of this phase, the rates were 21.99, 17.19, and 20.74 responses per minute for groups T-sh1, T-sh2, and T, respectively. These scores did not differ significantly ($F < 1$).

The right panel of Fig. 3 presents mean suppression ratios for each group during the 3 sessions of Phase 2. As expected, Group T-sh2 showed slower acquisition than Groups T and T-sh1, with this latter group showing faster acquisition than Group T. An ANOVA with Group and Session as the variables confirmed this ordering. There were significant effects of Group, $F(2, 21) = 6.93$, and of Session, $F(2, 42) = 192.44$, and a significant interaction between these variables, $F(4, 42) = 2.74$. Simple effect analyses conducted on this interaction revealed significant differences among the groups on Session 2, $F(2, 21) = 8.92$, and Session 3, $F(2, 21) = 6.05$, but not on session 1, $F(2, 21) = 3.03$, $p = 0.07$. Pairwise comparisons using Duncan tests showed that Groups T-sh2 and Group T suppressed less than Group T-sh1 on Session 2, and that Group T-sh2 suppressed less than Groups T-sh1 and T on Session 3. These results replicate findings of the two previous experiments, and provide direct evidence that an enhanced Hall–Pearce negative transfer effect is observed when positive transfer of associative strength is limited.

General discussion

Experiment 1 established that our procedures result in a reliable Hall–Pearce effect: CS-US_{weak} pairings retarded subsequent fear conditioning to the CS as a result of CS-US_{strong} pairings. As in previous studies (e.g., Hall & Pearce, 1979), the size of this retardation was less than that produced by standard latent inhibition training, consisting of CS alone presentations. When the magnitude of the US_{weak} was reduced in Experiment 2, the Hall–Pearce effect was revealed as greater retardation than latent inhibition. Experiment 3 confirmed the findings of the two previous experiments, and showed that magnitude of the Hall–Pearce negative transfer is inversely related to the magnitude of the US_{weak}.

Taken together, all these findings support the analysis that we offered in the Introduction. The overall effect produced by the Hall–Pearce treatment seems to consist of a balance between positive and negative transfer. On the one hand, CS-US_{weak} training allows acquisition of certain amount of associative strength by the CS, which results in a positive transfer to the learning of the CS-US_{strong} association. When this positive transfer is minimized—as was accomplished in the present study by reducing the magnitude of the US_{weak}—co-existing negative transfer effects become more evident, and deeper retardation is observed.

The nature of these negative transfer effects has been traditionally ascribed only to a loss of associability by the CS (e.g., Lubow, 1989; Pearce & Hall, 1980; Wagner, 1981; but see: Young & Fanselow, 1992). However, our results suggest that the effectiveness, or associability, of the US could also play an important role. In Experiment 2, reinforced preexposure to either the light or the tone retarded further conditioning to the tone with respect to equivalent nonreinforced preexposure conditions. We take this result as an instance of the well-known US-preexposure effect, with the preexposure to the US_{weak} reducing the effectiveness of the US_{strong} as a reinforcer. In the more conventional demonstrations of this effect, acquisition of the CR is retarded after prior exposure just to the event to be used as the US. However, it is well established empirically that the effect survives, although attenuated, under conditions very similar to those used in the Hall–Pearce paradigm: When the intensity of the shock-US used in conditioning does not exactly match that used in preexposure (e.g., Randich & LoLordo, 1979), and when the shock-USs are preceded during preexposure by a neutral stimulus, different than that used subsequently as the CS (e.g., Hall, Prados, & Sansa, 2005; Randich & LoLordo, 1979).

Following this analysis, our view is that the Hall–Pearce effect involves both CS- and US-preexposure effects. The sum of these effects results in greater overall negative transfer than that produced just by the CS-preexposure effect underlying latent inhibition. Whether or not this superiority is manifested as greater retardation in conditioning will depend on the degree to which the negative transfer is outweighed by the positive transfer of associative strength resulting from the CS-US_{weak} learning. Although this analysis is clearly in the spirit of theories emphasizing changes in the processing of both the CS and the US (e.g., Le Pelley, 2004; Wagner, 1981), what mechanisms might be responsible for these changes remain to be specified.

Two properties of stimuli have been traditionally proposed as able to modulate the amount of stimulus processing. The first of them is the ability of the stimulus to predict its consequences. Hall and Pearce gave extensive CS-US_{weak} training to the rats in their experimental group, with the intention of establishing the CS as an accurate predictor of its consequences (the US_{weak}). Following this analysis, retardation of the subsequent CS-US_{strong} learning was interpreted as supporting the notion that predictive accuracy of the CS tends to reduce (Pearce & Hall, 1980; see also Hall & Rodríguez, 2010), rather than to increase (Mackintosh, 1975), its processing. Support for the role of this mechanism has come from experiments showing that brief exposure to conditions which violate the predictive accuracy of the CS is enough to restore its processing (e.g., Hall & Pearce, 1982).

A second property of stimuli which has been proposed to modulate stimulus processing is the accuracy with which a stimulus is predicted by other events. More specifically, Wagner (1981; see also Rescorla & Wagner, 1972) proposed that a stimulus will be processed to the extent that its occurrence is not predicted by other present events (i.e., to the extent that its occurrence is surprising). In the Hall–Pearce paradigm, initial CS-US_{weak} training will ensure that not only will the CS be an accurate predictor of its consequences (via the formation of the CS-US_{weak} association), but also that the CS will be accurately predicted by the contextual cues. Repeated presentations of the CS in a given context are expected to promote the growth of associations between the context and the CS. The formation of these context-CS associations will thus reduce the amount of CS-processing, and accordingly retard the CS-US_{strong} learning. Evidence supporting the role of this mechanism was provided by Swartzentruber and Bouton (1986), who showed that the Hall–Pearce negative transfer effect was attenuated by a context switch between the CS-US_{weak} and CS-US_{strong} phases.

Wagner's mechanism also anticipates that, as we suggest, a reduction in the US-processing may contribute to the Hall–Pearce effect (see also Young & Fanselow, 1992). Repeated presentations of the US_{weak} during initial training will promote the formation of context-US_{weak} associations which will attenuate the processing of the US over the course of the subsequent CS-US_{strong} training. This analysis explains the US-preexposure effect observed in Experiment 2. There are reasons to think that this US-preexposure effect might be more dramatic in the Hall–Pearce experimental condition. During the initial CS-US_{weak} training, both the context and the CS will acquire the ability to predict the occurrence of the US_{weak}. Consequently, on the subsequent CS-US_{strong} trials, the occurrence of the US_{strong} will be less surprising (and will be less processed) because the preceding presentation of the same CS (the tone) will be signalling the occurrence of a weaker version of it.

In summary, the Hall–Pearce effect seems to be a complex phenomenon depending on several transfer effects and more than one mechanism for modulating stimulus processing. How these multiple mechanisms interact merits consideration in future research.

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