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A Comparison of Explicitly Unpaired Treatment and Extinction: Recovery of Sign-Tracking within a Context Renewal Design

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Abstract

The present experiment compared the effectiveness of explicitly unpaired treatment and extinction in preventing the recovery of sign-tracking within a context renewal design. Three groups of rats were first trained on a sign-tracking procedure in Context A where insertions of a retractable lever were paired with food. In a second phase, the sign-tracking response was eliminated. One group received standard extinction of the CS in Context B, while another group received explicitly unpaired treatment in Context B where food was presented only during inter-trial intervals (and not paired with the lever). A third group received this explicitly unpaired treatment in Context A. After the sign-tracking response was eliminated, all groups received a test session in Context A where the lever was presented alone and no food was delivered at any time. Significantly more responding occurred in the group that received explicitly unpaired treatment in Context B than in either of the other groups. This demonstrates that there are situations where explicitly unpaired treatment is less effective than extinction in preventing the reappearance of previously eliminated responding.

Keywords

Extinction; Explicitly Unpaired; Sign-tracking; Autoshaping; Resurgence; Context Renewal

1. Introduction

Explicitly unpaired (EU) training, as opposed to extinction, abolished the context renewal effect in conditioned suppression experiments (Rauhut, Thomas, and Ayres 2001; Thomas, Longo, and Ayres, 2005). In these studies, rats first received pairings of a conditioned stimulus (CS) with a footshock unconditioned stimulus (US) in Context A. The CS suppressed operant lever pressing for food. Then, in Context B, rats received EU presentations of the CS and footshock. This EU treatment eliminated the CS's suppressive effects of the CS on lever pressing. On a renewal test, animals returned to Context A and the CS was presented (without any USs). No renewal of suppression was observed. In contrast, renewal occurred in a group that received standard extinction (i.e., presentations of the CS only) in Context B. Similar results have recently been reported in a human fear conditioning study (Vervliet, Vansteenwegen, and Hermans, 2010).

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In sign-tracking (autoshaping) experiments, the simple discontinuation of EU treatment (without a context change) leads to a resurgence of responding. For example, Kearns and Weiss (2007) first trained rats on a procedure where retractable lever insertions were paired with a food US. Rats acquired a sign-tracking response directed at the lever CS. Sign-tracking was then eliminated through EU presentations of the lever and food. In a test phase, food presentations were discontinued and the CS was presented by itself. This produced a reappearance of sign-tracking. (Response rate increased from approximately 0 to 10 responses per minute, or to one-third of baseline levels.) Pavlovian resurgence¹ following the discontinuation of inter-trial interval (ITI) food has also been shown in several studies using pigeons as subjects (Colwill, 2007; Durlach, 1986; Epstein and Skinner, 1980; Jenkins and Lambos, 1983; Lindblom and Jenkins, 1981).

The results of Pavlovian resurgence studies suggest that, in contrast to the results of the aversive conditioning experiments described above, EU training (instead of extinction) in Context B might actually enhance, rather than abolish, the recovery of sign-tracking within a context renewal design. The present experiment investigated this question.

2. Methods

2.1 Subjects

Fourteen naïve adult male Long-Evans rats deprived to approximately 80% of their free-feeding weights (approximately 380 g) completed the experiment. (Three other rats were excluded because they failed to acquire sign-tracking.) Throughout the experiment, rats were treated in accordance with the Guide for the Care and Use of Laboratory Animals (National Academy of Sciences, 1996) as well as the guidelines of American University's Institutional Animal Care and Use Committee (IACUC).

2.2 Apparatus

Sessions occurred in Coulbourn Modular Test Cages (30.0 cm × 25.5 cm × 29.0 cm) equipped with two Coulbourn retractable levers located on the chamber's front wall. The left and right levers were positioned approximately 2 cm from the left and right side walls, respectively, and when inserted, extended approximately 1.5 cm into the chamber. A Med-Associates drinkometer circuit connected to the levers recorded lever-contact responses. There was no programmed minimum or maximum contact duration or time between contacts that defined a lever-contact response. One response was recorded regardless of whether the rat made a single brief contact with the lever or if the rat touched the lever and remained in contact with it for several seconds. A food receptacle was located on the front wall between the two levers. A speaker was located on the front wall approximately 18 cm above the food receptacle. This speaker was connected to a Med-Associates ANL 926 audio generator. A fan mounted on the back wall of the chamber could be activated to provide a moving air stimulus. The square frame that housed this fan measured approximately 12 cm × 12 cm and was positioned approximately in the center of the rear wall of the chamber. Each chamber was housed inside a sound attenuation chest that also had a continuously operating ventilation fan (separate from the stimulus fan). Experimental procedures were controlled by Med-Associates software (Med-PC).

¹The phenomenon was called "resurgence" in the first published report of the effect (Epstein and Skinner, 1980). However, this term has also been applied to the operant phenomenon where extinction of one operant response produces the reappearance of a second operant that had previously been eliminated by extinction (e.g., Epstein, 1985; Lieving and Lattal, 2003; Podlesnik, Jimenez-Gomez, and Shahan, 2006; Winterbauer and Bouton, 2010). To avoid confusion, the present paper uses the term "Pavlovian resurgence" to refer the reappearance of CS-elicited responding produced by the discontinuation of ITI US presentations.

In one of the two contexts, the fan on the back wall of the chamber was activated and an approximately 85 dB white noise was continuously presented through the front-wall speaker. In the alternative context, this fan and white noise were always turned off. For half the rats in each group Context A was the fan-on/noise context and Context B was the fan-off/no-noise context. For the other half of the subjects, these context designations were reversed.

2.3 Procedure

2.3.1 Phase 1: Sign-Tracking Acquisition in Context A—Phase 1 occurred in Context A for all groups. Rats received one magazine training session where 30 food pellets were delivered according to a variable-time (VT) 90-s schedule (range: 45-157). The levers remained retracted during this session.

Then, sign-tracking acquisition training began. The right lever was designated the CS⁺ lever and the left lever was the CS[−] lever. The CS⁺ lever was inserted into the chamber for a 15-s trial, and when it retracted, a food pellet was delivered. The frequency of CS⁺ trials was controlled by a VT 90-s schedule (range: 45-157). The CS[−] lever was also inserted for 15-s trials, but no food pellet was delivered when it retracted. Presentations of CS[−] trials were controlled by a separate VT 90-s schedule (range: 45-157). While one lever was inserted, the VT 90-s schedule controlling the other lever paused so that only one lever could be in the chamber at any time. A session consisted of 16 trials of each type (CS⁺ and CS[−]) and lasted approximately 32 min. Throughout all phases of the experiment, lever contacts were recorded but had no programmed consequences.

Rats were trained on this procedure for at least 12 sessions and until for two consecutive sessions these criteria were met: 1) the CS⁺ response rate was at least 10 responses per min, 2) the CS⁺ rate was at least 25% greater than the CS[−] rate, 3) the percentage of trials with at least one contact was at least 50% for the CS⁺ lever, and 4) the percentage of trials with at least one contact was greater for CS⁺ than for CS[−].

2.3.2 Phase 2: Response Elimination—Phase 2 began on the day after the last Phase 1 session. Rats were assigned to one of three groups: the Explicitly-Unpaired-in-Context B (EU-B) Group (n = 6), the Explicitly-Unpaired-in-Context-A (EU-A) Group (n = 4), or the Extinction-in-Context-B (Ext-B) Group (n = 4). Group assignment was made with the goal of matching groups on CS⁺ and CS[−] response rates after first counterbalancing contexts over A and B designations within each group.

The EU-B and EU-A Groups received EU training in Context B or Context A, respectively. Now, the CS⁺ and CS[−] levers were presented as frequently as before, but neither was paired with food. Instead, food was presented on a VT 15-s schedule (range: 1-29 s) during ITI periods when 1) neither lever was present, and 2) at least 15 s had elapsed since retraction of either lever. Approximately 70-80 food pellets were delivered per EU session. As previously, there were 16 trials each of the CS⁺ and CS[−] lever. Rats received 14 sessions on this EU procedure. The Ext-B Group was treated similarly except that no food was presented at any time during the session.

Test for Response Recovery: All rats then received a test in Context A on the day following the last Phase 2 session. This was an extinction session where both levers were presented as frequently as previously but no food was delivered at any time. There were 32 trials each of the CS⁺ and CS[−] levers.

Data analysis: For all statistical tests, $\alpha = 0.05$. Repeated-measures ANOVAs or one-way ANOVAs (followed by Bonferroni post hoc tests) were performed where appropriate on

CS⁺ and CS⁻ response rates from Phase 1, Phase 2, and the test session. CS⁺ response rates on the final Phase 2 session were compared to those on the test session to determine whether recovery occurred (Rauhut et al., 2001; Thomas et al., 2005).

3. Results

3.1 Phase 1: Sign-tracking

Thirteen of 14 subjects met the acquisition criteria within 12 sessions and one subject (in the EU-B Group) required 16 sessions. Figure 1 (left-most point) shows CS⁺ and CS⁻ response rates during the final Phase 1 session. A 3×2 (Group $\times$ Lever) repeated measures ANOVA performed on these rates revealed a significant main effect of Lever ($F[1,11] = 35.4$, $p < 0.001$), but no effect of Group ($F[2,11] = 0.1$, $p > 0.8$) and no Group $\times$ Lever interaction ($F[2,11] = 0.4$, $p > 0.65$).

3.2 Phase 2: Response Elimination

As Figure 1 (right portion) illustrates, the different treatments were equally effective in eliminating responding during Phase 2. A $3 \times 2 \times 14$ (Group $\times$ Lever $\times$ Session) repeated measures ANOVA performed on Phase 2 response rates revealed significant effects of Lever ($F[1,11] = 56.5$, $p < 0.001$), Session ($F[13,143] = 32.0$, $p < 0.001$), and their interaction ($F[13,143] = 26.3$, $p < 0.001$). There was no effect of Group ($F[2,11] = 0.8$, $p > 0.45$) and no interactions involving the Group factor (all F 's < 1 , all p 's > 0.5).

3.3 Test for Response Recovery

As Figure 2 illustrates, the EU-B Group made approximately 30 responses per min on the CS⁺ lever during the test, more than double the rate of either of the other two groups. All groups had relatively similar CS⁻ response rates, approximately 2-5 responses per min. A 3×2 (Group $\times$ Lever) repeated measures ANOVA performed on the test response rates revealed significant main effects of Group ($F[2,11] = 7.0$, $p < 0.05$) and Lever ($F[1,11] = 40.6$, $p < 0.001$) as well as a significant Group $\times$ Lever interaction ($F[2,11] = 10.9$, $p < 0.005$). One-way ANOVAs performed separately for CS⁺ and CS⁻ indicated that there was a significant effect of Group for the CS⁺ lever ($F[2,11] = 9.9$, $p < 0.005$), but not for the CS⁻ lever ($F[2,11] = 0.7$, $p > 0.5$). Bonferroni posthocs indicated that the EU-B Group responded at a significantly higher rate on the CS⁺ lever than the Ext-B Group ($p < 0.005$) or the EU-A Group ($p < 0.05$). There was no difference in CS⁺ rates between the two latter groups ($p > 0.8$).

A $3 \times 2 \times 2$ (Group $\times$ Session $\times$ Lever) repeated measures ANOVA performed on responses rates from the final Phase 2 session and the test session revealed that there was a significant Group $\times$ Session $\times$ Lever interaction ($F[2,11] = 9.3$, $p < 0.005$). Paired sample t-tests indicated that there was a significant increase in CS⁺ rate over sessions for the EU-B Group ($t[5] = 6.8$, $p < 0.005$) and the EU-A Group ($t[3] = 5.6$, $p < 0.05$), but not for the Ext-B Group ($t[3] = 1.7$, $p > 0.18$). There was no increase in CS⁻ rate for any group (all t s < 1.5 , p s > 0.24).

4. Discussion

The present experiment found that EU treatment enhanced, rather than abolished, recovery of sign-tracking within a context renewal design. The group (EU-B) that received EU treatment in Context B made significantly more sign-tracking responses during a renewal test in Context A than the group (Ext-B) that received extinction in Context B. Group EU-B also displayed significantly stronger recovery on the test than the group (EU-A) that

received EU treatment in Context A, indicating that the physical context change during Phase 2 treatment contributed to Group EU-B's recovery.

Despite the finding that Group EU-B made over 3 times as many CS⁺ responses as Group Ext-B on the test, EU training and extinction were equally effective in eliminating responding during Phase 2 training in Context B (see Fig. 1, EU-B vs. EU-A Groups). Vervliet et al. (2010) similarly found comparable effectiveness of EU treatment and extinction during Phase 2 in their aversive conditioning study, while Thomas et al. (2005) found somewhat slower loss of conditioned responding with EU training as compared to extinction. The Phase 2 results of the present experiment are also consistent with an earlier study showing that extinction and non-contingency training (food and CS presented randomly with respect to each other) reduced sign-tracking in rats at comparable rates (Locurto, Terrace, and Gibbon, 1976).

One explanation for the enhanced recovery in Group EU-B is that context renewal and Pavlovian resurgence processes summated in this group, while only one of these factors was operative in the other groups. A limitation of the present study that weakens confidence in this conclusion is that context renewal was not demonstrated by itself. This would require showing that test responding in Group Ext-B was either 1) higher than that in an Ext-A group (not run in the present experiment), or 2) higher than that during Group Ext-B's final Phase 2 session (not observed in the present experiment, perhaps due to the small *n*).

A question raised by this summation explanation is why Pavlovian resurgence did not also enhance recovery in the aversive conditioning experiments previously described (Rauhut et al., 2001; Thomas et al., 2005). That Pavlovian resurgence has only been observed with sign-tracking suggests that this phenomenon is response-specific. A behavior systems analysis (Timberlake and Lucas, 1989) might help account for such specificity. For example, it is possible that the sudden discontinuation of unsignaled food presentations to a hungry rat activates components of the feeding system's focal search mode that involve approaching and contacting stimuli once predictive of food. The defensive system might not be similarly engaged by the discontinuation of unsignaled aversive events. Instead, there might be a general deactivation of the defensive system, rather than a re-activation of system subcomponents.

An alternative to the summation account is that the recovery observed in Groups EU-A and EU-B was due only to context renewal. That is, ITI food presentations during Phase 2 acted as a contextual cue signaling that CS⁺ was no longer paired with food. During the test, ITI food presentations were discontinued and this cue was no longer present. This is why responding recovered in the groups that received EU treatment in Phase 2 (though see Colwill [2007] and Durlach [1986]). Greater recovery in Group EU-B Group as compared to Group EU-A occurred because the Phase 2 context change in Group EU-B (unsignaled food + changes in physical aspects of chamber) was more discernable than that in Group EU-A (unsignaled food only). A problem with this context account is that it is inconsistent with the results of the aversive conditioning experiments (Rauhut et al., 2001; Thomas, et al., 2005) where a physical context change plus ITI US presentations during Phase 2 abolished (rather than enhanced) the context renewal effect.

Regardless of the specific mechanism(s) underlying the present results, it is clear that EU training in Context B resulted in substantially more recovery of sign-tracking than did extinction. This suggests that there may be situations where EU treatment is not preferable to extinction as a method for preventing the reappearance of an unwanted behavior.

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Figure 1.

The point to the left of the dashed vertical line represents mean ($\pm$ SEM) lever contacts per minute on the CS⁺ (filled symbols) and CS⁻ (open symbols) levers during the final Phase 1 sign-tracking session (conducted in Context A for all groups). The points to the right of the line represent mean ($\pm$ SEM) responses per minute in CS⁺ and CS⁻ during Phase 2, which was conducted in Context A for Group EU-A and in Context B for Groups EU-B and Ext-B.

Figure 2.

Mean ($\pm$ SEM) lever contacts per minute on the CS⁺ (white bars) and CS⁻ (black bars) levers during the test session conducted in Context A for all groups. During the test, no food was delivered at any time and there were twice as many CS⁺ and CS⁻ trials as there were during Phase 1 and Phase 2 sessions. Note that the Y-axis scale is different from that in Figure 1.