RUNNING HEAD: EXPERIMENTAL RENEWAL

Experimental Renewal in Human Participants

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Abstract

Two experiments with human participants are presented that differentiate renewal from other behavioral effects that can produce a response after extinction. Participants played a video game and learned to suppress their behavior when sensor stimuli predicted an attack. Contexts (A, B, C) were provided by fictitious galaxies where the gameplay took place. In Experiment 1, participants that received conditioning in A, extinction in B, and testing in A showed some context-specificity of conditioning during extinction and a recovery of suppression on test. Experiment 2 demonstrated recovery of extinguished responding when participants were conditioned in A, extinguished in B, and tested in C, a third, neutral context. The experiment also demonstrated that the context of extinction did not control performance by becoming inhibitory. Results are discussed in terms of mechanisms that can produce a response recovery after extinction. The experiments demonstrated a renewal effect: A response recovery that was not attributable to the contexts acting as simple CSs and is the first work with human participants to conclusively do so.

Keywords: renewal, extinction, relapse, context, retrieval.

Experimental renewal in human participants

The present paper reviews mechanisms that might produce a recovery of responding following extinction. Then, two experiments with humans are presented that demonstrate "renewal" while dissociating it from simple associative mechanisms that might produce a recovery of responding. Renewal, or the "renewal effect," was discovered, and its mechanisms most thoroughly investigated, within an associative-learning framework based on animal research. Within that framework renewal referred to the recovery of an extinguished learned response as a result of a change in the context in which extinction occurred. To illustrate, consider a classic experiment by Bouton and King (1983). In their first experiment rats received pairings of a tone conditioned stimulus (CS) with a shock unconditioned stimulus (US) until the tone reliably elicited fear as indexed by response suppression. After conditioning, the animals were divided into three groups. Two of those three groups received extinction with the tone where it was presented without shock over several trials. One of those groups received extinction of the tone in the same context (conditioning apparatus) as where the tone-shock pairings occurred; typically referred to as "Context A." The other group received extinction of the tone in a different, but equally familiar, context "Context B." The third group received no extinction whatsoever. At that point in the experiment there was no obvious effect of the context switch. Throughout the course of extinction, rats that received extinction in Context B showed fear evoked by the CS that was indistinguishable from those receiving extinction in Context A. After the extinction phase, all rats received a test with the tone in Context A. For rats that received extinction in that context, the tone elicited very little fear. For rats that received extinction in Context B, the tone elicited a great deal of fear. The level of fear that recovered in that group on the first trial of the test was the same as that observed in the third group which had never undergone extinction. That recovery is labeled as "renewal."

In an influential series of papers Bouton (1993; 1994ab) described one plausible mechanism for the renewal effect in familiar terms found in associative learning. During initial learning, it is assumed that an excitatory association is formed between representations of the events (in this case, a CS and US). This excitatory association is diagramed as the arrow in Figure 1, Case A (Bouton, 1994a; Bouton & Nelson, 1994). The diagram, and the absence of an input from the context, is meant to imply that simple conditioning is relatively insensitive to contextual stimuli present during learning. During extinction, rather than unlearn that association it is assumed that new learning occurs in the form of inhibition (e.g., Wagner, 1981, 2003; Wagner & Brandon, 1989). Thus, at the end of extinction the CS controls two associations that interfere with each other leaving the CS neutral in its ability to retrieve associated events and affect behavior.

Unlike the initially learned excitatory association, the second-learned inhibitory association is assumed to be much more context-dependent. Inputs from the CS and the Context are required for the inhibition to be active and affect behavior (Figure 1, Case A, middle). When tested outside that context, the inhibition conditioned to the CS is not activated (Case A, right) allowing the expression of the earlier learning. The mechanism both accurately describes the phenomenon and is consistent with the definition offered earlier. Renewal occurs through this mechanism because something learned about the CS during extinction is controlled by the context and thus lost when the context changes.

The mechanism proposed by Bouton (1993) is fundamentally different than other, perhaps simpler, associative mechanisms that can lead to a response recovery after extinction. In some cases, a context can serve the role of a simple CS whereby it enters into associations with the US (see Bouton & Nelson, 1998, for review). That intuitive function provides at least three other reasons that a fear response might have been observed on the test in an "ABA" renewal paradigm (Cases B-D in Figure 1). One possibility is simple associative summation (Case B). It is well known that contexts can become associated with events presented within them (e.g., Grau & Rescorla, 1984; Fanselow, 1980; Iberico, et al. 2008; Rescorla, 1984). If the context functioned as a simple CS, then during conditioning in Context A both the CS and the Context could have become associated with the US (Case B, left). During extinction in Context B, the CS-US association may have indeed been reduced or "unlearned" as would be predicted by the Rescorla and Wagner (1972) model (Case B, middle). When returned to Context A the response observed could be a simple non-linear summation (e.g., Reberg, 1972) between the weak association controlled by the CS and that controlled by the context (Case B, right).

The next possibility, shown in Figure 1, Case C, is that the context where extinction took place became inhibitory. Conditioning in Context A could result in a strong CS-US association (Case C, left), but when the CS was presented without the US (which was expected as a result of conditioning) the context itself might acquire inhibition (Case C, middle). Here again the context may be serving the role of a simple CS. Because the context itself might signal that the US does not occur, and the resulting expectation matches the environmental contingency, there is no need to modify what is known about the CS. The context's inhibition would protect the CS from extinction (e.g., Lovibond, Davis, & O'Flaherty, 2000; Rescorla, 2003). Thus, when tested outside the context of extinction, a response to the CS would have been observed. The response would occur not because something that what was previously learned about the CS was renewed, but simply because of the removal of a source of inhibition external to the CS (Case C, right).

The final possibility, shown in Figure 1 Case D, is that during conditioning an association accrued not only to the CS and/or context, but also to some configural/unique cue (e.g., Pearce, 1994; 2002; Wagner, 2003) generated by their joint presence (Case D, left). During extinction in another context those configural cues available in the conditioning context would have been absent and would not have undergone extinction (Case D, middle). Recovery in the test context would simply be the result of the perception of those configural cues that never underwent extinction (Case D, right) rather than a recovery of something about the CS that was changed during extinction.

Recovery due to the mechanisms above (or combinations thereof), especially Cases B and D, can easily be thought of as different examples a simple generalization decrement (e.g., Brandon, Vogel, & Wagner, 2000; Holz & Azrin, 1963). The initial learned response, based on either excitatory or inhibitory conditioning, can be dependent on conditioning accrued to elements of the context or context/CS configuration. When these cues are absent due to contextual changes in extinction, they do not undergo extinction and thus it is difficult to accept the recovery as an example of renewal, a phenomenon that requires that extinction occur. A return to the conditioning context might not necessarily renew performance to the CS that has changed in some way: It simply allows responding to cues whose learned content has undergone little modification beyond the initial conditioning. Case C works in a similar way. That mechanism is one whereby a generalization decrement can attenuate what

was learned about the context or context/CS configural elements during extinction, allowing the expression of what was initially learned about the CS. With these three mechanisms, the participant need not modify what they have initially learned about the CS, rather, they may be learning directly about the context.

Although mechanisms represented in Cases B-D could produce a recovery of responding after extinction, renewal has been demonstrated in their absence. Thus, renewal has been differentiated mechanistically from the generalization-decrement effects discussed above. In their ABA design, Bouton and King (1983) demonstrated that recovery could be observed in the absence of demonstrable context conditioning at the time of testing. Such an observation helps to rule out the associative summation explanation offered above (Case B). Bouton and King observed equal conditioned responding to the CS immediately after conditioning and throughout extinction, regardless of whether the extinction was conducted in the same context as conditioning. That type of result provides additional evidence against the operation of the associative summation mechanism mentioned above in that method. That observation also eliminates an explanation based on a Context-CS configural-cue (Case C). If some portion of the conditioned responding were controlled by summation between the CS and the context or by a context-CS configural cue, then some deficit in responding should be observed when the CS was presented outside the conditioning context as it was during extinction.

Evidence against the context-inhibition mechanism (Case D) was also provided in the first experiment of Bouton and King (1983). In addition to conditioning with the tone CS, the rats received conditioning with a light. After the extinction phase with the tone, the light was extinguished in Context B in all three groups. For one group, extinction of the tone had occurred in that context, but not for the other two groups which received either extinction in Context A, or no extinction whatsoever. If the extinction had led to the context becoming inhibitory then Context B would have been inhibitory for the group that had received extinction there. Responding to the light should have been reduced more quickly in that group than in the other groups. Nevertheless, the groups did not differ in any measurable way in their extinction to the light in Context B. Corresponding evidence of a renewal effect in the absence of the mechanisms discussed above was also provided by Bouton and Swartzentruber (1986) and Rescorla (2008).

A mechanism of renewal like that proposed by Bouton (1993), rather than the simple mechanisms just discussed, connects it to numerous phenomena in learning theory and memory research. Through the constructs invoked by the mechanism, the renewal effect is linked to more than simply a recovery of conditioning performance due to a loss of contextually controlled extinction. In associative learning, renewal has come to represent a more general mechanistic principle whereby first-learned information can be expressed after learning contextually-controlled second-learned information. This link helped to establish the generality and relevance of the effect to much broader issues. Bouton (1991) demonstrated the relevance of the effect to a wide range of “interference” effects found in associative learning (see Bouton, 1991; 1993 for a review). Nelson (2002) expanded the mechanism experimentally by demonstrating that it is not necessarily inhibitory associations that are context specific, as implied by the mechanisms diagramed by Bouton (1994a) and Bouton and Nelson (1994). Rather, as both Bouton (1993) as well as Swartzentruber and Bouton (1992) suggested might be the case, it is second-learned information which becomes context specific. Inhibition acquired during

extinction is coincidentally the second type of information learned about the stimulus. Even simple excitatory associations between events can become context specific when they are the second types of information attached to a stimulus (see Nelson, 2002; 2009; for discussion). The effect has also been shown to be relevant to phenomena associated with occasion setting (Bouton & Swartzentruber, 1986; Bouton & Nelson, 1994; 1998; Nelson & Bouton, 1997). The mechanism has a role in associative learning's perceptual learning paradigms (Nelson & Sanjuan, 2008), and has implications for phenomena as diverse as emotional intelligence (Nelson & Bouton, 2002). The relevance of the effect for clinical psychology has been appreciated for over twenty years (Bouton, 1988; Bouton & Swartzentruber, 1991) in that it may serve the role of an animal model of relapse.

Borrowing from Rescorla's (2004) discussion of spontaneous recovery, renewal can likewise refer to an empirical manipulation, an empirical result, or a theoretical mechanism. As a manipulation, it refers to situations where a context is manipulated between extinction and testing, and it is typically clarified as a "renewal paradigm" (i.e., ABA, AAB, and ABC paradigms, where the letters refer to the contexts of conditioning, extinction, and testing, respectively). "Renewal" as a result is characterized by an apparent recovery of conditioned responding following extinction when the CS is tested in a different context than where extinction takes place. That is, it is the recovery observed in a renewal paradigm. Renewal as a mechanism is implied when the term is used as an explanation of a result or even another effect (e.g., spontaneous recovery is another example of renewal…"). The use here usually implies that a recovery is due to the loss of some contextually-controlled information conditioned to a cue. Whether that mechanism is that proposed by Bouton (1993; c.f., Larrauri & Smajuck, 2008), or not, the use of the term here does not imply the operation of the mechanisms shown in Cases B-D of Figure 1 from which it has been dissociated.

Interest in those broad connections, particularly those with clinical psychology, has stimulated multiple reports of renewal-like effects with human subjects using techniques varying from modifications of existing phobias (Mineka, Mystkowski, Hladek, & Rodriguez, 1999; Mystkowski, Craske, & Echiverri, 2002; Mystkowski, Mineka, Vernon, & Zinbarg, 2003), aversive conditioning (e.g., Effting & Kindt, 2007; Neumann, Lipp, & Cory, 2007; Vansteenwegen, et al., 2005), predictive learning tasks (e.g., Paredes-Olay & Rosas, 1999; Rosas & Callejas-Aguilera; 2006; Rosas, Garia-Gutierrez, & Callejas-Aguilera, 2006;), and conditioning within video games (e.g., Havermans, Kuker, Lataster, & Jansen, 2005; Neumann, 2006; 2007). What is presently lacking, however, is a demonstration of a recovery while assessing the mechanism by which it occurred. The full review is beyond the scope of this paper, yet no study presently demonstrates "renewal" in a manner that fits with all three possible uses of the term. None have fully ruled out the contribution of the mechanisms diagrammed in Figure 1, Cases B-D, with humans.

A few studies provide some control for these mechanisms, but ultimately fall short of fully achieving the goal. For example, Rosas and his colleagues (e.g., Rosas, et al., 2006) typically equate exposure to their various outcomes between contexts during training which should minimize potential differences in the associative status of the contexts. Yet extinction is only conducted in one context which might allow the associative status of the contexts to vary at that point. Neumann (2007), used a video game where participants learned to suppress responding in the presence of stimuli that predicted their responses would lead to an invasion of Martians (e.g., Arcediano, Ortega, & Matute, 1996). After

extinction in a different context provided by different room lighting and music, a return to the original context led to a recovery of response suppression. Additional exposure to the conditioning context was provided in the absence of the experimental stimuli to supposedly extinguish context-US associations. However, there was no control condition that did not receive such exposure to assess whether such associations might contribute to the observed recovery. There was no independent evidence provided that the exposure extinguished any presumed associations (c.f., Bouton & King, 1983), nor was there any assessment of whether the extinction context could have been inhibitory. Havermans et al., (2005) attempted to assess whether the extinction context in their preparation could become inhibitory by testing a non-extinguished CS there, but lacked a control group for which extinction had not occurred in the test context, preventing any firm conclusions from being reached. Thus, the goal of the present paper was to determine if renewal in human subjects could be obtained, while ruling out mechanisms that could operate when the context functions as a simple CS.

Experiment 1

The experiments reported here employed a video-game method used by Nelson and Sanjaun (2006; 2008). The game was conceptually the same as that of Arcediano, et al. (1996) which was used by Neumann (2006, 2007) as well as Havermans et al., (2005) to demonstrate recovery effects with changes in context. The versions of the game used by Neumann and Havermans et al. have demonstrated blocking (e.g., Arcediano, Matute, & Miller, 1997) and the version used here has demonstrated latent inhibition (Nelson & Sanjuan, 2006) and perceptual learning (Nelson & Sanjuan, 2008). Thus, it is a procedure that appears to involve basic associative processes and is not idiosyncratic to the phenomenon at hand. In our game a high-rate baseline of mouse-clicking was established by having participants fire torpedos at an on-screen spaceship. On this baseline, CSs (colored sensors) and USs (spaceship attacks) were presented. An attack from the spaceship drained the participant's power leaving them unable to play and produced an immediate response suppression. Participants were instructed that they should stop shooting when they expect to be attacked (to conserve their power), and came to suppress their mouse clicking in the presence of the sensor over trials.

The first experiment determined whether the method would produce an ABA recovery effect. The design is shown in the top portion of Figure 2. In Phase 1, participants played the game in Context A where a red sensor predicted attack. All groups received exposure to both Contexts A and B, with the context changing every six trials. For participants in Groups AAA and ABA all of their conditioning was conducted in Context A, with simple exposure to Context B. From Neumann's (2006, Experiments 2 & 3) findings (see also Havermans et al., 2005) we suspected that the conditioning in Context A might not transfer completely to Context B. Thus, the participants in Groups AAA_B+ and ABA_B+ received training to ensure that transfer. The trials were distributed in those groups so that half of the conditioning trials took place in Context B. In Phase 2, all participants received extinction, with extinction occurring in Context A for groups AAA and AAA_B+, and in Context B for Groups ABA and ABA_B+. Finally, all participants were tested for recovery in Context A. Because groups ABA and ABA_B+ were receiving a test outside the context of extinction, a recovery of responding was expected.

Method

Participants

Forty seven participants were randomly assigned to conditions. They were college students, (65.9% female), and between the ages of 18 and 25. Participants volunteered for "extra credit" in courses arranged through the relevant instructors of those courses, and alternative activities were available to obtain the credit. All procedures had been exempted for their simplicity by the institutional review boards from the institutions from which participants were obtained.

Apparatus

The exact same apparatus as was used and described by Nelson and Sanjuan (2006) was used here. The briefer description below is adapted from Nelson and Sanjuan (2008; pp 280-281; reprinted with permission). Participants received written instructions that they were playing a game where they were to earn points by shooting torpedoes at an onscreen spaceship by clicking the mouse. They were further instructed that sometimes they would be attacked, and that the attack would damage their spaceship by draining its power, leaving them unable to continue the game until their power was recharged. They were instructed that they could not avoid the attack, but that they could prepare for it by conserving their power through suppressing their own rate of torpedo firing when they believed they were about to be attacked. They were told that sensors would appear that might help them in the game and were not told what the sensors would indicate. The instructions were the same as those reported in detail in Nelson and Sanjuan (2006).

The video game was viewed on a standard 15-in (38.1-cm) computer monitor with a resolution of 800 x 600 pixels and 24-bit color depth. On the monitor an image was presented such that it was as if the participant were sitting inside of a spaceship looking out of a viewscreen. The viewscreen was a rectangular window 618 pixels wide and 368 pixels tall (23.5 x 14 cm) centered from left to right and 3.5 cm below the top of the screen on a grey metallic background. A box appeared 1.3 cm below the top of the screen in which the word "Points" appeared in yellow. At the bottom of the screen five black ovals appeared that were each 3.28 cm in diameter. The third was centered from left to right and located .8 cm above the bottom of the screen. The other four ovals were spaced at intervals of approximately 2 cm to the left and right of the center oval. One of three colored backgrounds (Hubble Space telescope photos of the Eagle 1 (predominately blue) or Crab Nebulae (predominately red), or the Swirl nebula (a predominately starless scene with brightly colored blobs) could be seen through the viewscreen on which a 3-dimensional representation of a spaceship was flying in a randomly determined path. These colored backgrounds provided contexts and were always counterbalanced.

Stimuli were presented as the 5-s illumination of the middle oval. The middle oval had a diameter of 85 pixels (approx. 3.28 cm on the screen) and a total area of 5310 pixels.

The hypothetical "unconditioned stimulus" was presented in the form of an inescapable attack from the enemy spacecraft. Immediately upon the offset of a sensor stimulus, a round, green, torpedo emerged from the onscreen spacecraft and exploded in the center of the viewscreen. The message, "Power at___ percent. Controls Frozen for ____ seconds." appeared in the center of the viewscreen and

remained until "Power" incremented to 100 and "Controls Frozen for ____" decremented to zero (changes occurring roughly every second). During this time, the computer mouse was inoperable and actions of the participant were not reflected on the screen. The numbers in the blanks were determined by a modified suppression ratio where the number of clicks during the 5-seconds prior to the attack (i.e., during the presentation of the sensor) was divided by that number plus the average rate of mouse clicks in the 5-seconds before stimulus presentations across the game. The resulting ratio was then multiplied by 120. For example, if a participant clicked, on average, 10 times prior to the sensor CS and did not suppress their rate of clicking, clicking 10 times during the sensor CS, the ratio would calculate to .5 and their controls would be frozen for 60 seconds by an attack.

Procedure

The experiment was announced to potential participants who had one month to volunteer for the study after the announcement. Participants were randomly assigned to conditions with no attempt to equalize group sizes (see the methods of Nelson & Sanjuan, 2008; for discussion). Each condition had an equal probability of being assigned to each participant.

Participants were seated at their respective computers and the written instructions were handed to them. They read the instructions silently to themselves, and then listened as the attending researcher read the instructions aloud. They placed their hand on the "s" key of the keyboard and were instructed to press it (starting the game) when the lights in the room were dimmed. The lights were then dimmed and the participants began the experiment.

Phase 1-Conditioning. Conditioning began in Context A (either the Eagle 1 or Crab nebula, counterbalanced). Throughout the course of the game participants clicked the left mouse button on a variable-ratio three schedule where a random one in three clicks launched a torpedo. A random half of those torpedos impacted the target spaceship. Participants in Groups AAA and ABA received six trials with the Red sensor paired with an attack with an average ITI of 11s (range 8-14 s). Participants in Groups AAA_B+ and ABA_B+ received three trials with the Red sensor with an average ITI of 22s (range 16-28 s), so that the total time spent in this context was the same.

A context switch to Context B was initiated with the appearance of a standard Microsoft Windows message box. The text, "Please attend to this important message" was displayed on the title bar of the message box and the text in the message box read, "You, your sensors, and the enemy are being transported to another galaxy for further testing. Press OK to proceed." When the participant pressed the "OK" button, another message box was displayed. The text, "Press OK now for immediate transport" was displayed in the title bar and the text in the message box read, "Remember, you, your sensors, and the enemy are being transported to another galaxy." When the participant pressed the "OK" button the screen flickered and the current background (e.g., Crab Nebula) was replaced with the alternative (e.g., Eagle 1 Nebula).

In Context B participants in groups AAA and ABA simply played the game with no other events occurring for the same amount of time as they experienced Context A. Participants in Groups AAA_B+ and ABA_B+ received three trials with the Red sensor paired with an attack as they did in Context A. The training in Context A and B just described was repeated for a total ABAB sequence.

Phase 2- Extinction. A context switch was then initiated for participants in Groups ABA and ABA_B+, while participants in Group AAA and AAA_B+ remained in Context A. During this time they

received 16 presentations of the Red sensor without an attack. The average inter-trial interval averaged 11s (range 8-14 s).

Recovery test. Groups ABA and ABA_B+ received a context switch back to Context A, while Groups AAA and AAA_B+ simply continued playing as in the previous phase. The red sensor was presented four times in extinction with an average ITI of 11s (range 10 - 12s).

Data analysis

The computer recorded the number of mouse clicks during the sensor CS presentations and during the five seconds before the sensor (pre-CS). These data were converted to standard suppression ratios (CS / (CS + Pre CS)) for analysis. Suppression ratio and pre-CS response-count data were analyzed separately with mixed-factorial analysis of variance (ANOVA) using the typical Type III (unique and unweighted) sums of squares.

Simple-effect tests were conducted with ANOVA using error terms derived from the overall analysis as described by Howell (1987). Degrees of Freedom were reduced using the Welch (1938) – Satterthwaite (1946) procedures to compensate for the pooling of potentially heterogeneous variances. Throughout, a rejection criterion of $p < .05$ was adopted and exact probabilities were reported for the reader.

For ANOVAs with more than one dependent variable, effect sizes were reported using partial eta-squared (η_p^2). Cohen's *d* was computed for pairwise comparisions. The *d* statistic was computed using the pooled variance around the two means being compared regardless of whether the comparison was between-subjects or within-subjects. Thus, throughout, the statistic most clearly represented the observable differences between the means given the unadjusted variability around each.

Following Nelson and Sanjuan (2006; 2008) participants with low levels of pre-CS responding (an average less than 1-click per second) were excluded. That criterion successfully excluded participants who sometimes had zero pre-CS responses, for which detection of suppression was impossible. Both extinction and detection of recovery depends on successful conditioning, thus participants whose suppression on two of the last three trials of conditioning was not greater than the first trial were excluded. The relationship between exclusion and group membership was analyzed with Chi-square tests of independence.

Results

Conditioned suppression was acquired equally, and at an equal rate, among the groups as shown above "Conditioning" in Figure 3. Extinction occurred in all groups, with extinction occurring more rapidly in Group ABA. On the test, a recovery of conditioned suppression was observed in Groups ABA and ABA_B+, with the overall level of recovery across the test being somewhat higher in Group ABA_B+.

Participant exclusion

Forty seven volunteers were randomly assigned to conditions with ns of 12, 12, 11, and 12 for groups AAA, AAA_B+, ABA, and ABA_B+, respectively. Application of the exclusion criteria eliminated one participant from group AAA, two from AAA_B+, two from ABA, and one from ABA_B+. Exclusion by any or all criteria was independent of group membership, χ^2's < 1.

Phase 1-Conditioning

Data from the conditioning phase are shown above "Conditioning" in Figure 3. During conditioning, suppression was acquired equally, and at an equal rate, between the groups. That description was confirmed with an Extinction Context (extinction in A or B) by B-Treatment (CS conditioned in B, or not) by Trials ANOVA. There was an effect of trials $F(11,407) = 28.19$, $p < .001$, $\eta_p^2 = .43$, as suppression was acquired, and no other effects, Fs ≤ 1.34, ps ≥ .19.

Responding in the Pre-CS was high, with some minor variability among trials. The same analysis of pre-CS responses showed a small effect of Trials, $F(11, 407) = 1.93$, $p = .03$, with response levels ranging between 17.0 on trial 1 to 20.7 on trial three. No other effects were reliable, Fs ≤ 1.29, ps ≥ .22.

Phase 2-Extinction

Data from the extinction phase are shown above "Extinction" in Figure 2. All groups showed equal levels of extinction by the end of the phase, but differed in their rates of extinction. Specifically, there were no detectable differences among the groups on the first trial, nor after the eighth trial. However, Group ABA showed a more rapid loss of suppression than the other groups where either extinction took place in Context A (Groups AAA and AAA_B+), or good transfer to Context B was expected (ABA_B+).

An Extinction Context x B-Treatment x Trials ANOVA showed an Extinction Context x Trials interaction, $F(15,555) = 2.89$, $p < .001$, $\eta_p^2 = .07$, and a reliable Extinction Context x B-Treatment interaction, $F(1,37) = 4.79$, $p = .04$, $\eta_p^2 = .11$. No other effects, not already superseded by the interactions, were reliable, Fs ≤ 1.28, ps ≥ .20.

Simple effect tests showed the Extinction Context x Trials and the Extinction Context x B-Treatment interactions to be due mostly to low suppression in Group ABA in the middle trials. There were no differences between groups AAA, ABA_B+ and AAA_B+ on any trial, Fs ≤ 3.68, ps ≥ .06. Group ABA differed from the other groups (Group AAA on trials 3-8, Group AAA_B+ on trials 2-7, and Group AAA_B+ on trials 3-7). In those comparisons Fs(1,134) ranged between 4.77 and 25.72, ps ≤ .032, ds ≥ 1.12. There were no differences on the first trial, Fs $\leq$ 1, nor after the eighth trial, Fs $\leq$ 3.56, ps $\geq$ .06.

Responding in the pre-CS averaged 19.6, and did not vary significantly across trials. The same analysis of responding in the pre-CS showed no effects, Fs ≤ 1.44, ps ≥ .12.

Recovery test

Groups ABA and ABA_B+ showed a recovery of response suppression when tested in Context A. The recovery was somewhat larger in Group ABA_B+.

The four test trials on the recovery test were analyzed with an Extinction Context x B-Treatment x Trials ANOVA. There was an Extinction Context x Trials interaction, $F(3,111) = 12.91$, $p < .001$ $\eta_p^2 = .29$, and an Extinction Context by B-Treatment interaction, $F(1,37) = 5.54$, $p = .02$, $\eta_p^2 = .13$. The Extinction Context x B-treatment x Trials interaction approached significance, $F(3,111) = 2.66$, $p = .052$. No other effects, not already superseded by a reliable interaction, were significant, Fs $\leq$ 1.94, ps $\geq$ .17.

Simple effect tests investigating the Extinction Context x Trials interaction showed that on the first trial there were no differences between the groups extinguished in Context A, $F < 1$, and none between the groups extinguished in Context B, $F < 1$. Each of the groups extinguished in Context A suppressed less than the groups tested in Context B, Fs(1, 73) ≥ 8.16, ps < .006, ds ≥ 1.09.

Simple effect tests investigating the Extinction Context x B-Treatment interaction (collapsed across trials) showed that Groups AAA_B+ and ABA_B+ differed in their average suppression across the test, $F(1,37) = 7.22$, $p = .01$, $d = 1.87$. Groups AAA and ABA did not differ in their average suppression across the test, $F < 1$.

Pre-CS responding decreased from an average of 21 to 19.7 across the test. The same analysis of pre-CS responding showed a small effect of trials, $F(3,111) = 3.33$, $p = .02$, but no other effects, Fs ≤ 1.

Discussion

The first experiment demonstrated several interesting effects. Extinction in Group AAA represented "normal" extinction with this method, and extinction in Groups AAA_B+ and ABA_B+ was indistinguishable from that normal extinction. Thus, when conditioning with the target stimulus had been conducted in both contexts, extinction in either was unaffected. But, when conditioning with the target stimulus had been conducted only in Context A, there was an effect of changing the context. Performance was lost more rapidly in Group ABA, thus, the context change seemed to engage some additional mechanism in that group. The groups did not differ on the first trial of extinction: Differences only emerged on Trial 2.

Other reports of ABA recovery in humans have suggested that their procedures did not result in context-specificity of conditioning, which would help to rule out a generalization decrement account of their recovery. However, many of these report analyses that may not be adequate to capture the effect. Procedures that report, or concentrate their analyses, only on the initial trial or trials of the context change (e.g., Rosas & Callejas-Aguillera, 2006; Rosas, García-Gutiérrez, & Callejas-Aguillera, 2006) may miss an underlying effect that could be masked by the response scale. Likewise, Vansteenwegen et al., (2005) reported that a change of context had no effect on the extinction of a conditioned skin conductance response, but only analyzed the first and last trials of extinction. As in our results, an inspection of their accompanying figure (Vansteenwegen et al., 2005, Figure 1, page 327) shows a rather large difference in the rate of extinction between the two contexts on the other trials that were not analyzed. A similar strategy was used by Üngör and Lachnit (2008), though the nature of their data left few alternative analysis strategies. Had such an analysis of only the first, or the first and last trials been reported here, the same, potentially incorrect, conclusion that conditioning performance was unaffected by a context change would have been reached. Such a lack of effect would have led us to conclude, perhaps erroneously, that any subsequent recovery was not due to summation between the test context and CS.

When tested in Context A, a robust recovery was observed. The mechanism of that recovery, however, was entirely ambiguous and we believe should not be labeled as renewal as it might imply a mechanism such as in Figure 1a. Recovery in group ABA could easily be due to any of the mechanisms cartooned in Figure 1, or any combination thereof.

The Renewal by B-Treatment interaction on the test was unexpected, yet simple to describe. The simple effect tests showed that Groups AAA_B+ and ABA_B+ differed when averaged across the course of the test, while differences between the AAA and ABA groups were only present on the first trial, and not when averaged across the test. Such a pattern simply indicates that the recovery in Group ABA_B+ was slightly more robust than in the ABA condition. That result is somewhat paradoxical on the one hand as the similar treatment of the CS across contexts during conditioning could have enhanced transfer between them (e.g., Hall & Honey, 1989). However, including additional common stimuli (i.e., the CS and the US) between the contexts could have also served to aid in their perceptual discrimination (e.g., McLaren & Mackintosh, 2000), reducing generalization between them.

Experiment 2

Experiment 2 was designed to demonstrate a recovery effect when the context was changed to a third, neutral context after extinction (ABC) and assess whether the extinction context acted as an inhibitor. The design is shown in the bottom portion of Figure 2. In Phase 1 all participants received conditioning trials with a red sensor intermixed with conditioning trials with a yellow sensor. During conditioning they received equal exposure to Contexts B and C. In Phase 2 they all received extinction with the red sensor in Context B.

Two groups received a recovery test. One group was tested with the red Sensor in Context A where any of the recovery mechanisms could produce recovery. The other group was tested in the neutral Context C, where recovery could be due to renewal or a release from context inhibition conditioned to Context B. On the fourth test trial the sensor was again paired with an attack simply to observe if suppression extinguished across the test would be recovered and whether the context of testing would have any impact on that recovery. Because the context was neutral, recovery there would rule out the participation of excitatory associative summation (Case B) and an excitatory configural-cue mechanism (Case D).

Two other groups received a summation test (Rescorla, 1969) to assess whether the context of extinction became inhibitory (Case D). Following extinction of the red sensor in Context B one group received extinction of the yellow sensor in that context while the other group received extinction of the yellow sensor in Context C. If the extinction context was inhibitory, extinction of yellow should proceed more rapidly in Context B than in Context C. Extinction in the previous experiments appeared to be nearly complete at about trial 7, so we conducted eight test trials. The first six test trials were in extinction, and the seventh involved a CS-US pairing. On that trial the yellow sensor was paired with the attack once more to determine if suppression extinguished across the test would be recovered, and whether the context would impact that recovery.

Method

Participants and apparatus

There were ninety nine volunteers in this study with the same characteristics of those in the previous studies. The same apparatus as was used in the previous experiment was used here. The three different backgrounds described in the apparatus of first experiment were counterbalanced between subjects as Contexts A, B, and C. To further enhance the differentiation between the contexts, the text

in the Microsoft Windows message boxes used to initiate context switches was changed. The words "another galaxy" were replaced with either "Blue galaxy," "Red galaxy," or "Swirl galaxy" depending on whether the galaxy was represented by the Eagle 1, Crab, or Swirl nebula backgrounds respectively.

Procedure

Participants began by playing the game for 96 seconds in Context B without any other events occurring. A context-switch was initiated and they received six conditioning trials with the red sensor in Context A, as was done with Group AAA in the first experiment, along with two conditioning trials with yellow (trials 2 and 7). A context-switch was then initiated and they played the game for 96 seconds in Context C with no events occurring. This sequence was repeated so that they received a total of 12 conditioning trials. In the second conditioning session in Context A, Yellow was paired with the US on trials 4 and 6. Following conditioning a context switch was initiated and they received 16 extinction trials in Context B. The inter-trial intervals were the same as in Experiment 1.

Following extinction Group Recovery A received eight test trials with the red sensor back in Context A while Group Recovery C received eight test trials with the red sensor in Context C. Inter-trial intervals averaged 11s (range 9-14s), and the first four were the same as were used on the test in Experiment 1. Participants received three non-reinforced presentations, one reinforced presentation, and four more non-reinforced presentations of the red sensor.

Groups Summation and Summation Control received a test with the yellow sensor. Both groups received six non-reinforced presentations of the yellow sensor, one reinforced presentation of the yellow sensor, and one more non-reinforced presentation. Testing for Group Summation was in Context B and that for Group Summation Control was in Context C. The inter-trial intervals were the same as in Groups Recovery A and Recovery C.

Data analysis

Data were collected and analyzed as in the previous experiment with one exception. Unlike the previous experiment, there was no manipulation here which might affect extinction between the groups: They all received the same treatment. Thus, in addition to excluding participants who did not show conditioning, we also excluded subjects who did not show extinction, which should maximize the possibility of detecting inhibition to the extinction context. Participants for whom suppression on two of the last three trials of extinction was not equal to or less than the first trial of conditioning were excluded.

Results

The data from the experiment are shown in Figure 4. For clarity the figure collapses across the identity of the groups in the first two phases as the groups were treated identically and did not differ in their performance. Suppression was acquired equally, and at an equal rate, between the groups. Likewise, extinction occurred equally, and at an equal rate, between the groups. On the recovery test, both groups tested in Context A and Context C showed recovery, with the recovery being somewhat larger in Context A. On the summation test, groups tested in either the potentially inhibitory Context B or the neutral Context C showed equal levels of suppression.

Exclusion

Random assignment placed 24, 21, 29, and 25 participants in Groups Recovery A, Recovery B, Summation, and Summation Control, respectively. Application of the exclusion criteria eliminated 8, 5, 6, and 3 participants from the groups, respectively. Exclusion based on any or all of the criteria was independent of group, χ^2 s ≤ 3.30, *p*s ≥ .35.

Training

Conditioning. Suppression to red and yellow was acquired equally between groups, as revealed by separate Trials x Group ANOVAs on responding to each CS. These analyses each showed effects of Trials, *F*s ≥ 61.92, *p*s < .001, η^2_p ≥ .46, and no other effects, *F*s < 1. The same analyses of pre-CS responding showed a small effect of Trials across the pre period before the red CS, *F*(11,803) = 2.67, *p* = .002, as responding increased from an initial average of 17.8 to 20.5 at the end. There were no other effects in the analyses, *F*s ≤2.42, ≥ .07.

Extinction. All groups showed extinction, as indicated by a Trials x Group ANVOA. There was an effect of trials, *F*(15,1095) = 50.95, *p* < .001, η^2_p = .41, and no other effects, *F*s < 1. The same analysis of pre-CS responding showed an effect of trials *F*(15,1095) = 7.10, *p* < .001. Average pre-CS responding on trial two (15.9) was slightly below that of the other trials which ranged between 20.2 and 21.1.

Testing

Recovery test. Both groups showed recovery when compared to the last trial of extinction, with the recovery being somewhat larger in Group Recovery A. That recovery extinguished across trials. Pairing the CS with the US on trial 4 reinstated suppression to the two groups equally that persisted across the remainder of the test. These data are shown in Figure 4 in the second to last panel.

The last trial of extinction was compared to the first trial of testing in Groups Recovery A and Recovery C with a Trials x Group ANOVA. The analysis showed a main effect of Trial, *F*(1,30) = 58.36, *p* < .001, η^2_p = .66, and no other effects, *F*s ≤ 2.98, *p* ≥ .09.

Though the interaction was not reliable, there was an a-priori reason to expect the recovery in group Recovery C to be less than that of Recovery A, (see Harris, Jones, Bailey, & Westbrook, 2000; Neumann, 2006) thus the groups were investigated more closely with simple effect tests. As indicated by the overall analysis, from the last trial of conditioning to the first trial of testing there was recovery in both groups, *F*(1,30) = 40.93, *d* = 2.26 for Group Recovery A and *F*(1,30) = 19.42, *d* = 1.58 for Group Recovery C. Contrary to what the lack of an interaction in the overall analysis suggested, there was no difference on the last trial of extinction, *F* < 1, but there was a detectable difference on the first trial of the test, *F*(1,60) = 4.91, *p* = .03, *d* = .57.

All four of the first four trials of the test were analyzed with a Trial by Group ANOVA that revealed an effect of Trials, *F*(3,90) = 29.35, *p* < .001, η^2_p = .49, and no other effects, *F* ≤ 2.87, *p*s ≥ .1.

The effect of the sensor-attack paring on trial 4 was assessed by comparing suppression on trial 4 with that on trial 5 with a Trial by Group ANOVA. There was an effect of Trials, *F*(1,30) = 73.04, *p* <

.001, η^2_p = .71, and no other effects, *F*s < 1. A Trials by Group ANOVA of the last four trials showed no effects, *F*s ≤ 1.3, *F*s ≥ .33.

Summation test. Both Group Summation and Group Summation control showed less suppression to the yellow sensor on the test than on the last trial of conditioning. That suppression extinguished across the first seven trials of the test. The CS-US pairing on trial 7 reinstated suppression on Trial 8 to an equal level in both groups. The two groups did not differ on any trial.

The last conditioning trial with yellow between Groups Summation and Summation Control was compared to the first trial of the test with a Trial by Group ANOVA. The test data are shown in the right-most panel of Figure 4. The analysis showed an effect of Trial, $F(1,43) = 18.4$, $p < .001$, $\eta^2_p = .30$. No other effects were reliable, *F*s < 1. A Trials by Group analysis of the first seven trials showed an effect of Trials, $F(6,258) = 48.43$, $p < .001$, $\eta^2_p = .53$, and no other effects, *F*s ≤ 1.13, *p*s ≥ .34. Simple effects of Group on each trial confirmed the overall analysis showing no differences between groups on any trial, *F*s $\leq$ 1.63, *p*s $\geq$ .20. A Trial x Group ANOVA on trials 7 and 8 showed that suppression increased after the final sensor-attack pairing, $F(1,43) = 109.56$, $p < .001$, $\eta^2_p = .72$. No other effects were reliable, *F*s ≤ 2.45, *p*s ≥ .12.

Pre-CS. Pre-CS responding on the tests averaged 20.6 during the test phases and was consistent within subjects across trials which led to many seemingly spurious significant effects in the several analyses conducted. As has been the case thus far, these effects were meaningless in the interpretation of the suppression ratio data. The largest difference between the number of responses during any two pre-CS periods across the test was on trial 5 between Group Summation (17.2) and Group Summation Control (20.5). Those two groups had near identical suppression ratio's on that trial (.471 and .474, respectively) and adjusting either by the three-response difference in pre-CS responding did not alter the analysis. Moreover, analyses of responding in the CS mirror the suppression ratio analyses. When baseline responding is high, as in these studies, these small difference have no meaningful impact on the suppression ratios. Indeed, some authors choose not to report analyses of pre-CS responses even when baseline responses are considerably lower (Havermans, et al., 2005; Neumann, 2006). For brevity, further analysis of the pre-CS responding are not reported.

Discussion

In the present experiment two groups received conditioning in Context A, extinction in Context B, and a recovery test in Contexts A or C. Recovery was evident in both groups, with possibly somewhat stronger recovery in Context A than in Context C, which is consistent with previous comparisons of ABA to ABC designs (e.g., Effting & Kindt, 2007; Harris, Jones, Bailey, & Westbrook, 2000; Neumann, 2006).

The ABC renewal design is particularly effective at ruling out the influence of the test context being excitatory. Few papers with humans have convincingly demonstrated the effect (Üngör & Lachnit, 2008). Some attempts have not demonstrated an ABC recovery effect (e.g., Havermans et al., 2005), while others have done so somewhat ambiguously due to their use two CSs (e.g., Effting & Kindt, 2007; Neuman, 2006). In those works, conditioning, extinction, and testing were conducted with one CS (the

CS+), and throughout these phases participants received exposure to another (the CS-). When conditioning, extinction and testing were conducted in Contexts A, B, and C, respectively, a recovery effect was observed with CS+, but a response was also observed to the CS-. The response to the CS- was presumably unconditioned as it had never been paired with the US. At face value, such an effect on the CS- questions whether there was recovery of the initial learning with the CS+, or also some unconditional response to the CS+ in the new context. Whether these responses to the CS- were unconditional or not is unclear: Contextual changes can cause discriminations to break down (see Nelson & Sanjuan, 2008). Thus, a lack of difference between a CS+ and CS- on test in Context C could represent an ABC recovery, as well as a failure to fully discriminate the CS+ and CS- (see Üngör & Lachnit, 2006 for a similar breakdown in discrimination on test in an ABC design).

The recovery we observed in Context C cannot be attributed to associative summation nor a recovery of some configural cue developed in Context A. Thus, that recovery appears to be due to the removal of some influence of Context B. The learning in extinction was more affected by a context change than was the learning during conditioning. Context B could be modulating what was learned about the CS during extinction (e.g., Case A), or functioning as a CS and inhibiting the US directly (Case D). These possibilities were assessed with two other groups that received the same treatment through conditioning and extinction as the groups showing recovery. During the test, they were presented with a non-extinguished CS in either the context where prior extinction had occurred, or in a neutral context. If the context of extinction had become inhibitory, there should be less suppression to the CS in that context than in the neutral Context C.

Between the last trial of training with that CS in Context A and the first trial of testing in contexts B or C, there was a loss of suppression in both groups being tested (see also Havermans et al., 2005). Whether that loss was due to the context change between training and testing, the short passage of time between training and testing, some generalization of extinction from the red sensor, or any other factor is unknown. What is clear from that analysis is that responding on the first trial of the test was not at a response floor. There was room to see a difference between the groups if they existed, and no difference was observed. Over the next six trials of testing suppression reliably decreased. Thus, on the first trial suppression was also clearly not at a ceiling, so again there was room in the response scale to see differences if they existed. Pairing the Sensor CS with the attack on the 7th trial led to an increase in suppression in both contexts, and again responding did not vary between the contexts. Across a wide range of suppression levels there were no differences in suppression to the test CS when it was tested in a potentially inhibitory context, or a neutral one.

Inhibition may not have accrued to the context directly, but to a configural cue of the context and CS. Such a configural explanation can account for the recovery effects reported by Üngör and Lachnit (2006; 2008). According to the models of Wagner (2003) and Pearce (1994), if the context and CS had entered into some type of inhibitory configuration, there should have been some generalization of that inhibition to the test CS/context compounds, which was not observed. Thus, there was no evidence that the context became inhibitory during extinction. Like Bouton and King (1983) the present experiment has shown a recovery effect in the absence of the context controlling inhibition in any simple CS-like fashion. This experiment is the first with human participants regarding recovery effects

that has included a control group to adequately assess whether the context of extinction can become inhibitory (c.f., Havermans et al., 2005)

From these two tests a recovery of responding to an extinguished CS was observed in a neutral context where recovery could not be due to the test context serving any role as a simple CS while also observing that there was no inhibition conditioned to the extinction context. Thus, the recovery appeared due to losing something about the CS learned during extinction that was controlled by the extinction context. The recovery was not due to losing or gaining information about the US controlled by the contexts directly. That is, renewal was observed. No demonstration of response recovery with a particular method should be attributed to renewal as a mechanism without conducting tests to rule out the contributions of both the test and extinction contexts functioning as simple CSs.

General Discussion

The present work was undertaken to demonstrate a renewal effect with human participants, and to differentiate it from simpler forms of response recovery. A context can serve as a CS, and enter into excitatory and inhibitory relationships with the US, and thus produce a recovery of responding through a variety of mechanisms as outlined in the introduction. Renewal, on the other hand, is usually viewed mechanistically as a recovery effect that is due to a loss of contextual control acquired when some new interfering information about a stimulus is learned about the stimulus itself. Though popular and highly plausible, we should acknowledged that that explanation is but one of potentially many possible ways to characterize the effect (e.g., Larrauri & Smajuck, 2008). Despite its plausibility, no direct evidence for that description (i.e., Case A) as a mechanism is available. Rather, it has been inferred by ruling out alternatives. Regardless of the mechanism that one believes best fits the data (e.g., Bouton, 1993; Larrauri & Smajuck, 2008), available evidence can speak to what it is not. Renewal is not a recovery due to the context serving as a CS. Such effects are dissociable from renewal.

There are two important findings in Experiment 1. In addition to observing a robust response recovery following extinction when tested back in the conditioning context, conditioned responding was shown to be somewhat context specific. That context-specificity is always a complication in the interpretation of the mechanism responsible for recovery in an ABA design. What is further important about that observation is that it was not evident early in extinction, but emerged over training. Methods and analyses that focus on the first trial after a context switch can fail to discover that underlying context-specificity.

The final experiment assessed whether the extinction context reduced responding to the CS by acting as an inhibitory CS itself. Four groups received conditioning with two CSs in Context A and extinction with one of those stimuli in Context B. Two groups were then tested either in Context A or C with the extinguished CS and both showed recovery. Recovery in C was perhaps less than that in A, suggesting that some mechanism consistent with the CS and conditioning context creating an excitatory configural cue may also be operating in our ABA design. Such a mechanism could not be present in the group that was tested in C as that context was associatively neutral. The other two groups received a test of the non-extinguished CS in the extinction context or in Context C. These groups did not differ in their responses. Thus, it did not appear that the extinction context functioned as an inhibitory CS. By

including a proper control condition, this experiment is the first with humans to adequately address whether the extinction context becomes inhibitory (c.f., Havermans et al., 2005).

The design of the final experiment demonstrated renewal in that it ruled out known alternative behavioral effects that can lead to a recovery through mechanisms by which the context functions as a CS. That is not to say that these mechanisms cannot lead to recovery in some preparations, but they are not mechanisms typically evoked by use of the term renewal. Renewal is perhaps best characterized as a particular type of recovery where responding controlled by the CS is recovered because something about the CS learned in extinction was controlled by the context in which it was learned, and thus lost when that context was changed. No demonstration of response recovery with a particular method should be attributed to renewal as a modulatory mechanism (e.g., Case A) without conducting tests to rule out the contributions of both the test and extinction contexts functioning as simple CSs.

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Figure captions

Figure 1: Four mechanisms of recovery. Case A: Conditioning (left) results in the formation of relatively context-independent excitation (arrow) between event representations. Extinction (middle) creates new learning (inhibition-blocked line) that interferes with the original learning. New learning is assumed to be context dependent in that its expression (right) depends on input from both the CS and the context where it was acquired. Case B: Contextual and CS stimuli become associated with the US during conditioning (left) and unlearning takes place during extinction (middle). Recovery results from summation between a weak CS and the Context (right). Case C: The CS becomes associated with the US during conditioning (left). In extinction (middle) the extinction context becomes inhibitory. Recovery results from removing the inhibition provided by the extinction context (right). Case D: Conditioning (left) results in associations forming between elements of the CS and Context, as well as parts unique to their co-occurrence (X). Extinction decrements the CS-US association (middle), and recovery results from a recovery of the X elements unique to the co-occurrence of the CS and Context (right) that did not undergo extinction.

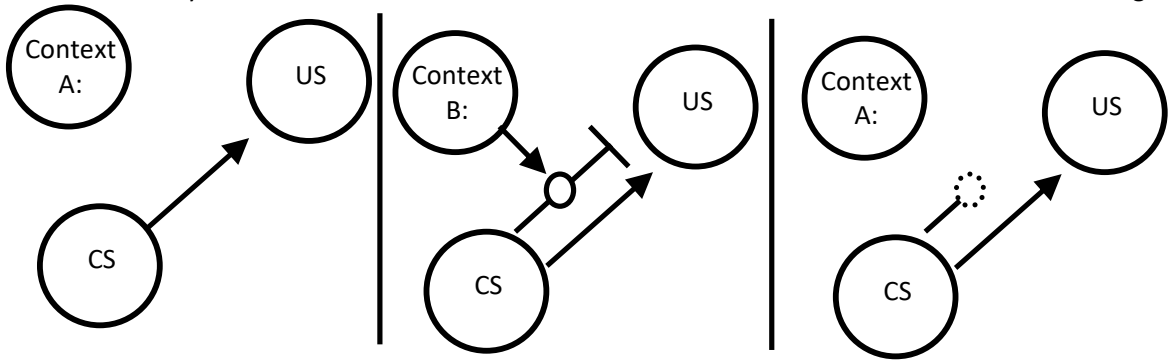
Figure 2: The design of the experiments. A: and B: are contexts provided by fictitious galaxies in a video game. R and Y are red and yellow sensor CSs. '+' and '–' represent an inescapable attack from an enemy spaceship, or not, respectively. Slashes represent intermixed trials. See text for details.

Figure 3: Suppression ratio data from Experiment 1. Conditioning is shown at left, extinction in the middle, and the two recovery tests at right. Vertical bars represent the standard-error of the mean. See text for details.

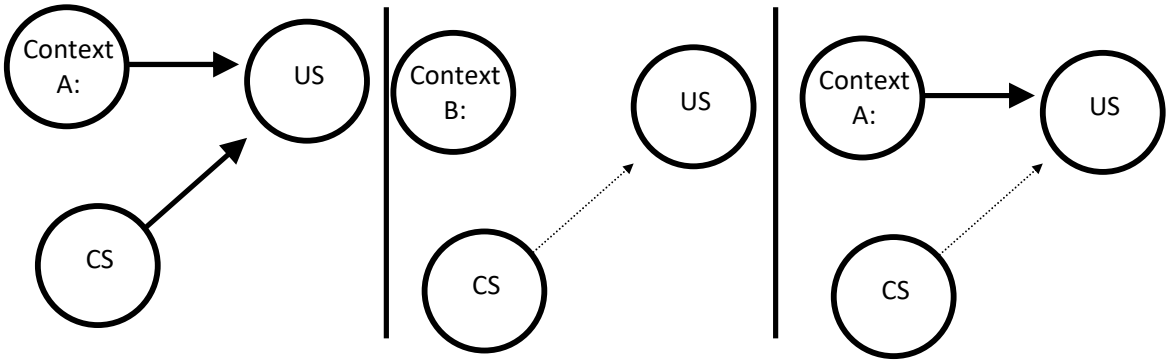
Figure 4: Suppression ratio data from Experiment 2. Conditioning with red (black squares with asterisk) and yellow (open squares) is shown at left, extinction with red is shown in the middle. The next panel to the right shows the recovery test conducted in Context A (solid symbols) or Context C (open symbols). Final panel shows the test with yellow in the context where extinction of red occurred (Summation, solid triangles) or in a neutral context (Summation Control, open triangles). The US was delivered on trial 4 of the test in the Renewal Test Groups and on trial 7 of the test in the Summation Test Groups. Vertical bars represent the standard-error of the mean. See text for details.

Case A: Recovery as contextual modulation of extinction

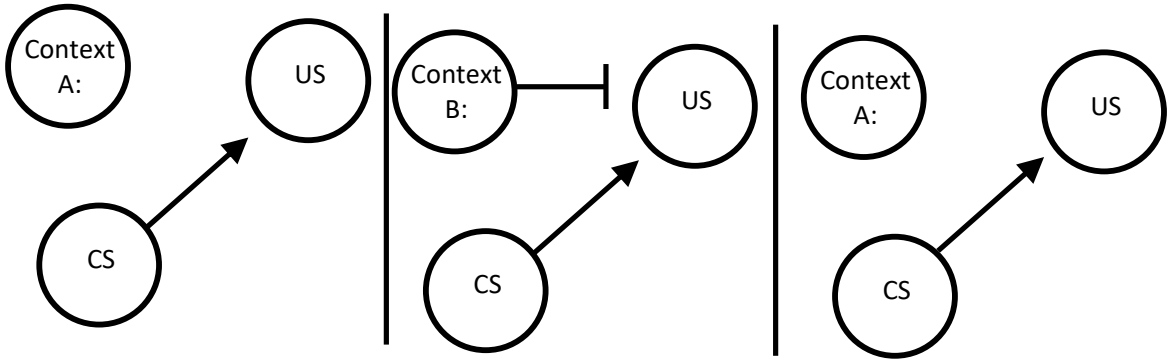
Figure 1



Case B: Recovery as associative summation



Case C: Recovery as release from inhibition (Protection from extinction)



Case D: Recovery as configural learning

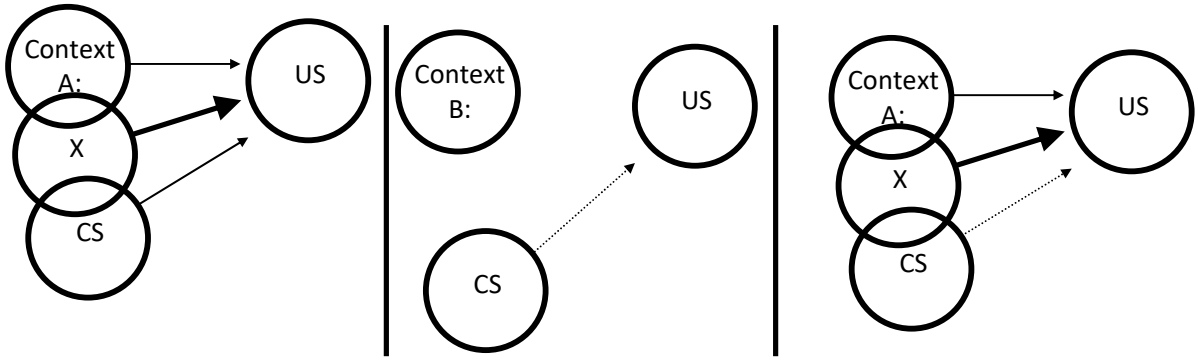


Figure 2

Experiment	Group	Phase 1	Phase 2	Recovery Test
1	AAA	A: R+ / B:-	A: R-	A: R-
	ABA		B: R-	
	AAA_B+	A: R+ / B: R+	A: R-	
	ABA_B+		B: R-	
2	Recovery A	A: R+,Y+ / B: -/ C:-	B: R-	A: R-
	Recovery C			C: R-
	Summation			B: Y-
	Summation Control			C: Y-

Figure 3

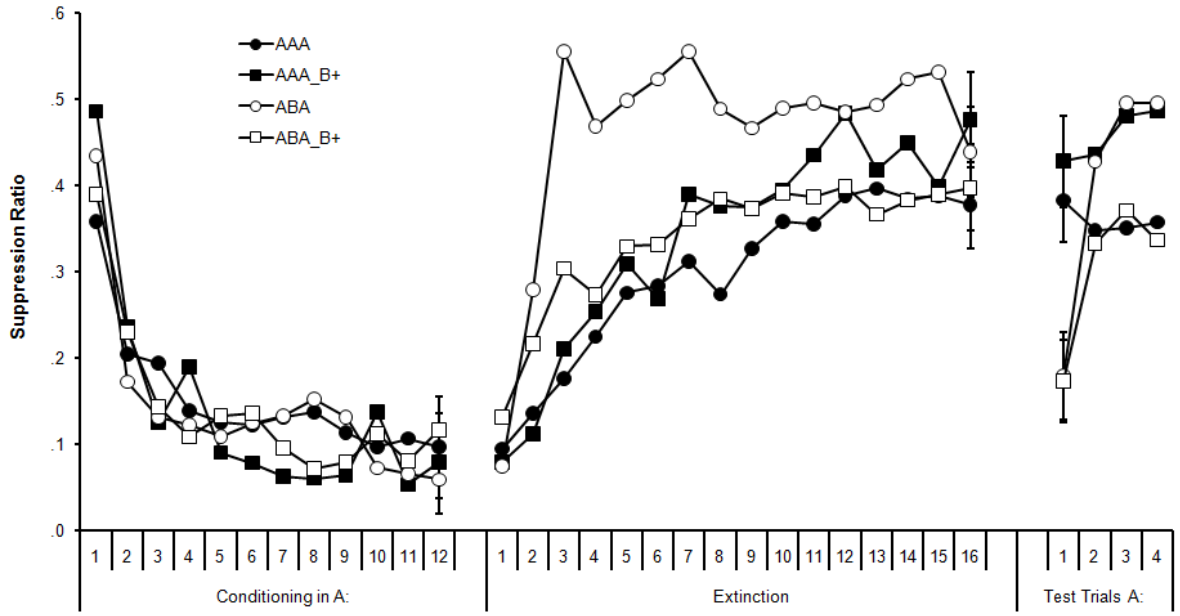
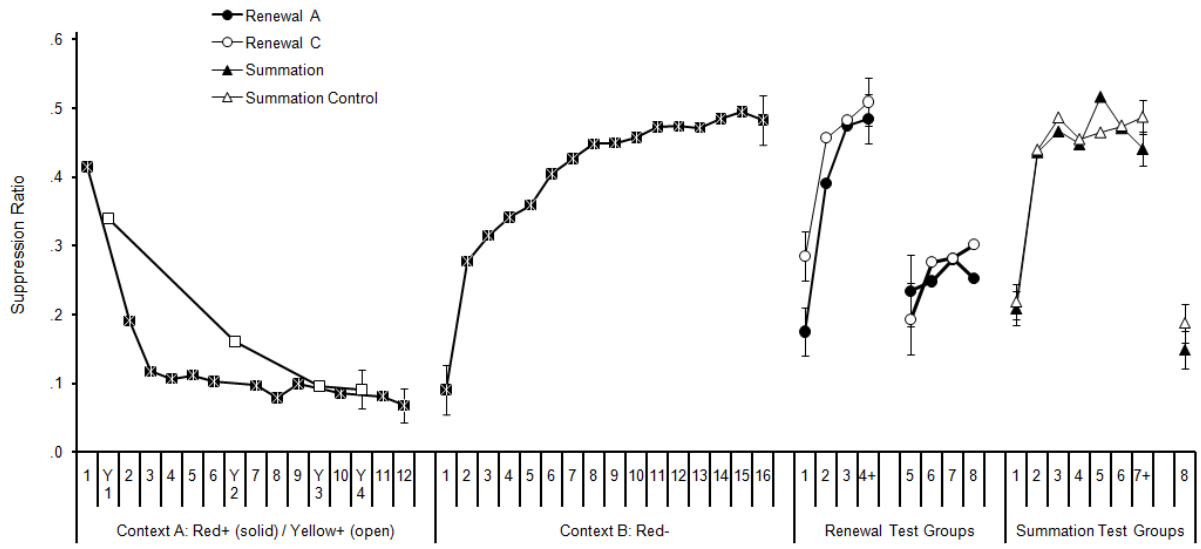

AAA
AAA_B+
ABA
ABA_B+
Suppression Ratio
.6
.5
.4
.3
.2
.1
.0
1 2 3 4 5 6 7 8 9 10 11 12
Conditioning in A:
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Extinction
1 2 3 4
Test Trials A:

Figure 4


Renewal A
Renewal C
Summation
Summation Control
Suppression Ratio
.6
.5
.4
.3
.2
.1
.0
1 Y 1 2 3 4 5 6 Y 2 7 8 9 Y 3 10 Y 4 11 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
1 2 3 4+ 5 6 7 8
1 2 3 4 5 6 7+ 8
Context A: Red+ (solid) / Yellow+ (open)
Context B: Red-
Renewal Test Groups
Summation Test Groups