Published in final edited form as:

Behav Processes. 2012 July ; 90(3): 372–377. doi:10.1016/j.beproc.2012.04.001.

The extinction context enables extinction performance after a change in context

James Byron Nelson, Ph.D.¹, Pamela Gregory, BS², and Maria del Carmen Sanjuan, Ph.D.³

James Byron Nelson: JamesByron.Nelson@ehu.es; Maria del Carmen Sanjuan: mariadelcarmen.sanjuan@ehu.es

^{1,3}Universidad de Pais Vasco, Sarriena, s/n 48940-Leioa (Bizkaia), SPAIN

²College of Charleston, 66 George Street, Charleston, SC, 29424 USA

Abstract

One experiment with human participants determined the extent to which recovery of extinguished responding with a context switch was due to a failure to retrieve contextually-controlled learning, or some other process such as participants learning that context changes signal reversals in the meaning of stimulus – outcome relationships. In a video game, participants learned to suppress mouse clicking in the presence of a stimulus that predicted an attack. Then, that stimulus underwent extinction in a different context (environment within the game). Following extinction, suppression was recovered and then extinguished again during testing in the conditioning context. In a final test, participants that were tested in the context where extinction first took place showed less of a recovery than those tested in a neutral context, but they showed a recovery of suppression nevertheless. A change in context tended to cause a change in the meaning of the stimulus, leading to recovery in both the neutral and extinction contexts. The extinction context attenuated that recovery, perhaps by enabling retrieval of the learning that took place in extinction. Recovery outside an extinction context is due to a failure of the context to enable the learning acquired during extinction, but only in part.

Keywords

Extinction; human; renewal; retrieval

1. Introduction

The renewal effect refers to the recovery of an extinguished response with a change in the context where extinction took place. When a response is acquired to a CS in one context (Context A) and extinguished in another (Context B), the conditioned response returns when testing is conducted either back in Context A, or in a context different from the extinction context (e.g., Context C). The effect can also be observed when conditioning and extinction occur in the same context and testing occurs in another (see Rescorla, 2008, for examples). Such recovery is not limited to conditioning and extinction, but also occurs in counter-conditioning (e.g., Peck & Bouton, 1990) where a conditioned stimulus (CS) is first

© 2012 Elsevier B.V. All rights reserved.

Correspondence : James Byron Nelson, Depto. Procesos básicos y su desarrollo, Avenida de Tolosa, 70, Universidad de País Vasco, San Sebastián, Spain, 20018, Jamesbyron.nelson@ehu.es, DrJBN@hotmail.com, Phone: 34 943 01 52 23.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

associated with one unconditioned stimulus (US) such as food, and then a different US (e.g., shock). It has relevance to the interference paradigms found in associative learning (Bouton, 1991), occasion setting (e.g., Nelson & Bouton, 1997), behavior therapy (e.g., Bouton & Nelson, 1998), and phenomena as diverse as emotional intelligence (Nelson & Bouton, 2002).

The explanation for the effect that is most often invoked is that offered by Bouton (1993). Bouton assumes that an excitatory association is acquired between the relevant events during conditioning and that that initial association is comparatively independent of the context where it was acquired. Behavior consistent with the nature or valence of the association will be predominately expressed regardless of the context where the stimulus is tested. When new contingencies are encountered after the initial conditioning, new learning is assumed to occur. That new learning (inhibition in the case of extinction), is assumed to depend upon both associative input from the stimulus and the context to be expressed in behavior. Thus, when the stimulus is tested outside the extinction context the new learning that occurred there is not activated and behavior consistent with the original learning is expressed. Though invoked most often, that explanation is not the only one available (e.g., Larrauri & Schmajuk, 2008).

Renewal is taken as an example of extinction learning being context specific, yet demonstrations of renewal with humans (e.g., Nelson et al., 2011) have largely confounded a change in context with the identity of the test context. For example, in a standard ABA design where initial conditioning takes place in Context A, extinction in a different context (B) and testing occurs back in Context A, the relevant controls receive either an AAA or ABB treatment. In the controls there is no change between the context of extinction and testing. Thus, whether or not testing occurs in an extinction context is confounded with whether a context change occurs at all. That confound is an important consideration as Pineño and Miller (2004) suggested that changes in context can come to generally signal a change in stimulus meaning, at least in humans. Rather than the context being associated with particular learning episodes and enabling the associations acquired in those episodes, as Bouton (1993) proposed, Pineño and Miller suggest that context changes simply signal that the meaning of a stimulus should change, switching between available meanings acquired throughout the experiment. They do not, however, offer a precise mechanism by which such a switching process operates.

In their experiments participants played a video game where they took the role of a United Nations soldier responsible for loading refugees onto a truck. The truck then encountered one of three road conditions in its journey. The road could be mined and the refugees would all die. The road could be free of mines and the refugees would escape to safety. Finally, the road could be blocked which would force the truck to return to camp and the refugees would neither die nor escape. The soldier had a “spy radio” that contained colored lights which could indicate the status of the road. The participant was to learn which road condition was indicated by each light. When participants believed the road was safe they were to load refugees onto the truck by clicking an on-screen button with the mouse, otherwise they should not put refugees onto the truck.

In the critical experiment, cues X and Y were paired with different outcomes in an Acquisition phase. X was paired with the road being mine free, while Y was paired with the road being blocked. Then, those outcomes were reversed in an Extinction phase. Extinction was followed by a Reacquisition phase, and finally a Test. The critical group, A-E-R-T, received an extraneous stimulus (a putative context change) between each phase. Here, the screen of the computer was blackened for 30 seconds and the participant was informed that they had the opportunity to rest before continuing. According to Pineño and Miller’s (2004)

hypothesis, participants should have learned that each presentation of the extraneous stimulus signaled a change in the meaning of the stimuli. Thus, on test, they would express behavior consistent with the E phase where Y predicted that the road was open and X predicted that the road was closed. Another critical group, AER-T received the extraneous stimulus before the test, but as that was the only time it had been encountered they had not had the opportunity to learn the correlation between the extraneous stimulus and the changes in the meaning of the cues. On the test, group A-E-R-T showed performance consistent with the E phase. They responded more to Y than to X, but such a reversal was not obtained in group AER-T. Thus, it did appear that participants treated the extraneous stimulus as a signal for the meaning of a cue to revert to a previous meaning. Pineño and Miller did not suggest that their mechanism was a replacement for that offered by Bouton (1993), but rather that it might be an additional mechanism through which renewal could occur in humans.

The present experiment was designed to determine whether renewal in humans might be conceptualized as a failure to retrieve extinction learning while assessing the impact of simply changing the context. Both the experimental and control groups received a context switch, either into a context associated with extinction, or not, respectively. Thus, both the mechanism proposed by Bouton (1993) and one such as that of Pineño and Miller (2004) could operate. Pineño and Miller (2004) had suggested that both mechanisms could be operating in demonstrations of renewal, but there was nothing present in their data that necessitated that suggestion. With varying degrees of strength, all reports of renewal with human participants can be attributed to a Pineño and Miller-type mechanism.

The experiment used the same video-game method and procedure as Nelson, Sanjuan, Vadillo-Ruiz, Perez, and Leon (2011), to remain consistent with a method in which renewal has been demonstrated in the absence of demonstrable context-US associations. Such associations would compromise the ability of recovery to be interpreted as contextual control of learning about the CS during extinction. First, a high baseline of mouse-click responding was established by having participants fire torpedoes at a spaceship in a video game. During conditioning, colored sensors at the bottom of the screen predicted when the participant was about to be attacked by the spaceship; a situation where the participant should conserve power by withholding shooting. Thus, learning the sensor-attack relationship was indexed by response suppression. Next, all participants underwent extinction in a different context provided by a different space background upon which the game took place. In this phase, the sensor was presented without an attack. After extinction the sensor was presented back in the context where conditioning took place in an ABA recovery test. A recovery of response suppression was expected in that context, which was then extinguished during the recovery test. All groups were treated identically up until the crucial test that followed the recovery test. Thus, the intervals between the initial recovery test and the final test were identical between groups.

The final test context was varied between groups. Participants in Final Test A received no change of context immediately before the final test. They received continued testing in Context A, the context where conditioning, recovery testing, and re-extinction had most recently occurred. Participants in Final Test B received a test with the sensor in Context B, where extinction had taken place prior to the recovery test. Participants in Final Test C were tested in a third context that was associated with neither conditioning nor extinction. Participants in Final Test B and Final Test C both received a context switch on test, with only the context's association with extinction manipulated.

Both theories make similar predictions regarding groups Final Test A and Final Test C. Both theories predict continued extinction performance in Final Test A. Both theories predict

some recovery of responding in Final Test C. There, the test context is different from that in which extinction took place, thus the theory of Bouton predicts that there should be a loss of the new learning enabled by the extinction context and a recovery of the original learning and response. Likewise, because a context change occurred during extinction when the meaning of the stimulus changed, participants could have learned that changes in context indicate that the meanings of stimuli also change. According to the conclusions of Pineño and Miller a recovery of the original meaning of the stimulus would be expected when tested in Context C.

The predictions differ concerning group Final Test B. Context B is the context where extinction initially took place. According to Bouton (1993), the context should retrieve the learning that occurred during extinction and no recovery of suppression would be expected. Based on the mechanisms proposed by Pineño and Miller, the identity of the context should not matter so long as there is a change between contexts. If participants treat context changes as indicators of a change in the meaning of the stimulus, then with the context change from the recovery test in Context A to the final test in Context B, there should be a recovery of suppression.

This test is an important test as contextual control of extinction is inferred by the observation that extinction performance is lost with a change in context. Demonstrations of that “renewal” effect confound the identity of the context (associated with extinction or not) with whether or not a change in context occurred. In the present test, that confound is broken. Participants in Final Test B and Final Test C all experienced a change in context, with only the identity of the test context manipulated. It should also be noted that accounts of recovery effects which rely on configural cues (e.g., Pearce, 1994), or elements unique to stimulus configurations (Wagner, 2003), make the same prediction as Bouton. If the parameters of the method were such that participant’s experience with changes in context during training led to those changes no longer being perceived as a novel, then the model offered by Larauri and Schmajuk (2008) would make the same prediction as Bouton (we return to this possibility in the Discussion). In all the theories described above, when tested in Context B the representations and associations responsible for eliminating the suppression response should be completely restored, resulting in no return of suppression, regardless of whether testing in B is accompanied by a change.

2. Materials and Methods

2.1 Participants

There were 54 participants in this study. They were college students, 65% female, and between the ages of 18 and 25. Participants volunteered for “extra credit” in courses arranged through the teachers of those courses, and alternative activities were available to obtain the credit. All procedures were approved by the institutional review boards from the institutions from which participants were obtained.

2.2 Apparatus

The exact same apparatus as was used and described in detail by Nelson and Sanjuan (2006; 2008; Nelson et al., 2011) was used here. The description below is adapted from Nelson and Sanjuan (2008; pp 280–281; with permission). Participants received printed instructions (see Nelson & Sanjuan, 2006) stating that they were playing a game and could 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 drain their spaceship’s power leaving them unable to continue the game until their power was recharged. Participants were informed that they could not avoid the attack, but that they

could prepare for it by conserving their power (suppressing their own rate of torpedo firing) when they were about to be attacked.

The video game was viewed on a 38.1-cm computer monitor. An image was presented as if the participant was sitting inside of a spaceship looking out of a viewscreen. At the bottom of the monitor five black ovals were visible, centered, and spaced at intervals of 2 cm. Three colored backgrounds were available, provided by Hubble space telescope photos of the Eagle nebula (“Pillars of creation” area), Crab nebula (predominately red), or the Swirl nebula (a predominately starless scene with bright multicolored blobs) upon which a 3-dimensional representation of a spaceship was moving in a randomly determined path. These backgrounds provided contexts and were always counterbalanced. CSs were the 5-s illumination of the middle oval with the color red.

When presented, the hypothetical “unconditioned stimulus” was an inescapable attack from the enemy spacecraft. Immediately upon the offset of the sensor, 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). The numbers in the blanks incremented or decremented as described in Nelson and Sanjuan (2006). During this time, the computer mouse was inoperable and actions of the participant were not reflected on the screen.

2.3 Procedure

The experiment was announced to potential participants and conditions were randomly assigned 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 computer and 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 dimmed and the participants began the game.

2.3.1 Conditioning—Participants played the game for 96 seconds in Context B with no events occurring and were then trained in Context A. Context changes occurred as they did in Experiment 2 of Nelson et al., and involved presentation of two standard Microsoft Windows message boxes informing the participant that he or she was being transported to another galaxy for further testing (e.g., “You, your sensors, and the enemy spacecraft are being transported to _____ for further testing” with the name of the galaxy in the blank), followed by a change in the space background of the game. Each time participants were in Context A they received six conditioning trials with a red sensor where the sensor was illuminated for 5 s followed by an attack US with an average inter-trial interval (ITI) of 11.26 s (range 8–14 s).

Another context-switch was then initiated and they played the game for 96 seconds in Context C with no events occurring. This B-A-C sequence was repeated so that participants received a total of 12 conditioning trials.

2.3.2 Extinction—Following conditioning a context switch was initiated and participants received 16 extinction trials in Context B. The inter-trial intervals averaged the same as in conditioning.

2.3.3 Recovery test—Following extinction, a context switch was initiated and participants received four test trials in Context A with an inter-trial interval of 11 s (range 10 – 12 s) and no USs present.

2.3.4 Final test—Participants in Group Final Test A continued to play the game uninterrupted. Participants in Group Final Test B received a context switch to Context B, and those in Group Final Test C received a context switch to Context C. All participants received four test trials with the red sensor as in the Recovery Test.

3. Data analysis

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

Although most authors (e.g., Havermans, Keuker, Lataster, & Jansen, 2005) do not report pre-CS responses when analyzing suppression ratios from human participants, they are reported here to fully characterize the data. Though occasional near differences were observed in pre-CS responding, they did not compromise our conclusions. Participants responded at rates from three to five responses per second and small variations in that rate had minimum impact in the suppression ratios. For example, if a participant responded only three times during the CS it made no difference in the reliability of the effect whether their pre-CS count was 19 (suppression ratio = .14) or 25 (suppression ratio = .11).

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 two levels of the dependent variable, effect sizes were reported using partial eta-squared. Cohen's d was computed for pairwise comparisons. The d statistic was computed using the pooled variance around the two means being compared regardless of whether it was a between-subject or within-subject comparison.

Following our previous reports (Nelson & Sanjuan, 2006; 2008; Nelson et al. 2011) participants with low baseline responding (an average less than 1-click per second) were excluded. That criterion successfully excluded participants who had zero pre-CS response rates on some trials, for which detection of suppression was impossible. Detection of recovery depended on both successful conditioning and extinction, thus both participants whose suppression on two of the last three trials of conditioning was not greater than the first trial, and those 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. The relationship between exclusion and group membership was analyzed with Chi-square tests of independence.

4. Results

4.1 Exclusion

Random assignment placed 18, 19, and 17 participants in groups Final Test A, Final Test B, and Final Test C, respectively. Application of the exclusion criteria removed five, four, and

two participants from each group, respectively. The exclusion criteria were independent of group, $\chi^2(1) = 1.39$, $p = .50$.

4.2 Conditioning

The conditioning data are shown in Figure 1, left. Suppression was acquired equally across trials in all groups. A Trials $\times$ Group ANOVA showed an effect of Trials, $F(11,440) = 27.21$, $p < .001$, $\eta^2_p = .40$, and no other effects, $F_s < 1$. The same analysis of pre-CS responding showed a small ($\eta^2_p = .07$) Trials by Group interaction, $F(22,4440) = 1.66$, $p = .03$. Simple effect tests showed that on Trial 11 Group Final Test A showed slightly less responding (mean 15.31) than did Group Final Test B (mean = 19.93) or Final Test C (mean = 20.2), $F_s(1,69) = 4.51$, $p < .04$. There were no other differences in pre-CS responding which averaged 18.06 during conditioning.

4.3 Extinction

The data from Extinction are shown in Figure 1, middle. Suppression decreased equally across trials for all groups. A Trials $\times$ Group ANOVA of the data from extinction showed an effect of Trials, $F(15,600) = 57.64$, $p < .001$, $\eta^2_p = .40$, and no other effects, $F_s = 1.45$. The same analysis of pre-CS responding showed no effects, $F_s = 1.23$.

4.4 Recovery test

Data from the recovery test are shown in Figure 1, second to last set of points. All groups showed a recovery of suppression when tested back in Context A that extinguished across test trials with no differences between groups. The data were first analyzed with a Trial by Group ANOVA comparing the last trial of extinction with the first trial of the recovery test. There was an effect of Trial as all groups showed recovery, $F(1,40) = 114.93$, $p < .001$, $\eta^2_p = .74$, and no other effects, $F_s < 1$. Analysis of pre-CS responding showed no effects, $F_s = 3.16$. The average pre-CS response on the last trial of extinction was 16, 18.87, and 18.2 for groups Final Test A, Final Test B, and Final Test C, respectively. The average pre-CS response on the first trial of test was 18.23, 19.4, and 17.67, for groups Final Test A, Final Test B, and Final Test C.

A Trials by Group ANOVA on all four test trials showed an effect of trials as the recovery extinguished, $F(3,120) = 71.73$, $p < .001$, $\eta^2_p = .64$, and no other effects. Analysis of pre-CS responding showed no effects, $F_s = 1.89$.

4.5 Final Test

Data from the final test are shown in Figure 1, right. Group Final Test A showed continued extinction performance. As expected, Group Final Test C showed a recovery of suppression. Group Final Test B also showed a recovery of suppression, but less of a recovery than Group Final Test C.

The data were first analyzed with a Trial by Group ANOVA comparing the last trial of the Recovery test to the first trial of the Final test. There was an effect of Trial, $F(1,40) = 13.48$, and a Trials by Group interaction, $F(2,40) = 4.46$, $p = .02$, $\eta^2_p = .25$. The same analysis of pre-CS responding produced no effects, $F_s < 1$.

Analysis of all four trials by Group showed an effect of Trials, $F(3,120) = 13.57$ and a Trial by Group interaction, $F(6,120) = 3.77$, $p = .001$, $\eta^2_p = .16$. The same analysis of pre-CS responding produced no effects, $F_s = 2.43$. The maximum pre-CS response was 18.14 on trial 2 and the minimum was 16.78 on trial 3.

Simple effect tests on trial one revealed that both Final Test B and Final Test C showed recovery relative to Final Test A, $F(1,154) = 8.54$, $p = .004$, $d = .84$. Final Test C showed stronger recovery than Final Test B, $F(1,154) = 5.15$, $p = .02$, $d = .48$. Pre-CS rates averaged 17.38, 18.4, and 16.73, for groups Final Test A, Final Test B, and Final Test C, respectively on that trial, and did not differ, $F_s < 1$.

5. Discussion

Contextual control of extinction is most often assumed to underlie the renewal effect where recovery of extinguished responding is observed when testing is conducted outside the extinction context (Bouton, 1993). Reports of renewal with humans typically confound the test context's association with extinction with the change of context that occurs when testing outside that context. The present experiment was conducted to determine the extent to which the test context's association with extinction contributes to extinction performance, and thus its loss in a different context, or if simply switching contexts could lead to a recovery independently of the treatment of the CS within it (e.g., Pineño & Miller, 2004).

The experiment was designed to observe the contribution of each potential mechanism; the ability of the context to enable extinction, and the ability of change to disrupt ongoing performance. Participants received training in Context A, extinction in Context B, and a recovery test in Context A where responding was further extinguished. Participants were tested once more either in Context A where extinction had just re-occurred, Context B where extinction initially took place, or Context C in which neither CSs nor USs had been encountered before. On the recovery test all participants showed a strong recovery of responding that had extinguished in the previous phase. Although there was no control condition that received testing in the context where extinction had just occurred (seen Nelson et al., 2011), it was very unlikely that the substantial increase in suppression observed on the test was the result of random variation in the stable response pattern observed over the last 10 trials of extinction. Following the initial recovery, suppression extinguished during the first test. On the final test, participants tested in Context A continued to show performance consistent with the extinction that had occurred on the previous test. Participants tested in Context C, a neutral context, showed a recovery of suppression. Participants tested in Context B also showed a recovery of suppression, but less of a recovery than those tested in Context C.

Those data indicate that multiple mechanisms were at work in the recovery of responding that we observed. Recovery in Context B indicated that changes between contexts, or at least the perturbation in the event sequence caused by the context-change procedure, do affect the meaning of the CS. Context B was associated with extinction, thus, based exclusively on the idea that renewal effects occur due to a failure of the test context to enable learning associated with extinction, no recovery of conditioning performance should be expected. Nevertheless, some recovery did occur in that context. That recovery was, importantly, less than the recovery observed in the neutral Context C. That difference shows that although some change in the meaning of the stimulus occurred, that change was incomplete. The extinction context did appear instrumental in enabling extinction performance despite the tendency for the meaning of the stimulus to change with the change in context.

The observation of less recovery in an extinction context than in a neutral context is an important observation. Extinction contexts are thought to enable or retrieve something about the extinction experience, producing performance associated with that phase. Evidence for that assertion in humans comes from studies of renewal where a change out of the extinction context leads to recovery of initial learning, ostensibly due to a loss of contextually controlled extinction learning. Such demonstrations involve a comparison between testing in

a context where extinction was conducted and a different context. Tests in a context different from where extinction took place are necessarily accompanied by a change *out* of the extinction context. In the present experiment testing in both Contexts B and C was accompanied by a change of context, leaving only the context's association with extinction as the sole variable. Less responding was observed in B than in C, confirming that the extinction context does enable or retrieve extinction performance as suggested by the theorizing of Bouton (1993).

The Schmajuk, Lam, and Gray (SLG) model (Schmajuk, Lam & Gray, 1996) can also explain these particular results if it can be assumed that the change in context was perceived, as the model predicts, to be a somewhat novel event (see the application to "renewal" in Larrauri & Schmajuk, 2008). According to the model two things would occur during extinction. Context B would become inhibitory and attention to both the CS and context would decline. The decline in attention would limit the ability of either the CS or context to control behavior. The model predicts that the context change immediately before the final test was perceived as a novel event which would restore attention to the CS and Context. During extinction, attention to the CS would have declined less than to the context which received more overall exposure, permitting attention to the CS to be better restored than to the context. Thus, some response to the CS would be observed, but less than what would be observed in a neutral context because of the presence of inhibition conditioned to the extinction context.

The explanation provided by the model presented in Larrauri and Schmajuk (2008) is attractive in its simplicity. Changing contexts simply increases attention, resulting in a re-expression of previously acquired learning. Though attractive and a good candidate for conceptualizing these results, there are two issues regarding the treatment of the constructs it involves, attention and novelty, which lead us to remain tentative about this explanation presently. First, in the course of the experiment participants experienced the context-change procedure seven times prior to the final test. Recall from the method that each change in context was accompanied by two message boxes that indicated, by name, to which context the participant was being transported to in the game. Thus, whether or not a change into a context would still be perceived as novel on the eighth change before the test, as predicted by the model, is uncertain.

Second, the model predicts that the extinction context should become inhibitory during extinction. Rather than enable a particular meaning of the stimulus, the context itself would mean that no outcome was forthcoming. While that result can be obtained with the selection of some methods and parameters (see Polack, Laborda, & Miller, 2012), there is no evidence for that result with the present method. With the present method and procedures (Nelson et al., 2011) the extinction context failed a summation test for inhibition (e.g., Rescorla, 1969), a finding that is comparatively consistent with results from rats (e.g., Bouton & King, 1983). Extinction of a test CS was no more or less rapid in a context where extinction with another stimulus had occurred than in a neutral context.

The SLG model does generally predict the null result described above. Attention to the context should be low, and therefore the inhibition to the context would not be observed unless something unexpected, such as the presentation of a novel CS, occurs and restores that attention. Indeed, Kutlu and Schmajuk, (2012) have demonstrated with a predictive learning task that an inhibitory CS is better able to control behavior after being paired with a novel CS. In Nelson et al., the test CS had never been experienced in the test context, and it had always been reinforced. It is reasonable to assume that both the six non-reinforced presentations of the test CS, and its presence in the test context, would have been novel events, thus attention to the context would have been restored. On the seventh trial of the

test the US was re-introduced, which contrasted with what had occurred on the previous six trials, and produced strong suppression again. From that suppression, it appears as though the reinforced trial was effective in arousing attention in both experimental and controls groups. Nevertheless, no differences in responding between the groups were observed on any trial. In both Nelson et al. and the present experiment, robust learning in the conditioning, extinction, and test phases occurred within six trials. The number of the trials used on the test appeared, empirically, to be sufficient to arouse attention. In short, the results obtained by Kutlu and Schmajuk with discrete CSs in a predictive learning task have yet to be demonstrated with tonic background contextual stimuli.

The present experiment was designed to assess the impact of changing the context, but it did not provide an explicit test of the exact mechanism proposed by Pineño and Miller (2004). In Pineño and Miller's work, breaking the correlation between contexts and changes in the meaning of a stimulus broke the ability of the stimulus to signal "change." Similarly, our procedure should have undermined the operation of such a mechanism. Consistent with Nelson et al., (2011) we took care to ensure that the test contexts were not novel by equating exposure to the contexts during conditioning. Participants had experienced each context twice during conditioning. In that way, the procedure created context switches that were not accompanied with the CS, and thus not accompanied by changes in its meaning. The correlation between a change in the meaning of the stimulus and a change in context only occurred when the context was switched to Context B in extinction. The first test could have undermined the Pineño and Miller mechanism as it was conducted in extinction. Participants consequently received a context change accompanied with the stimulus, but the outcome of the stimulus did not change.

Procedural details likely minimized the operation of a pure switching mechanism as envisioned by Pineño and Miller (2004), yet a change in context resulted in some change in the meaning of the stimulus. Nevertheless, over and above the effect of change, the relationship of the context to the events occurring within it was important. The way in which the stimulus-outcome relationship changed during extinction enabled the context with the ability to at least partially enable that new CS-US relationship. While change itself may disrupt the current meaning of a stimulus, the experiment demonstrated that contexts can still enable extinction performance of stimuli that have been extinguished within them.

6. Conclusions

Contexts appear to retrieve or otherwise enable the learning about CSs that takes place within them. Nevertheless, when a CS is associated with multiple outcomes capable of supporting different behaviors, the events involved in changing a context are themselves important. The change itself tends to degrade the ability of the CS to control behavior consistent with its most recent conditioning experience over those acquired earlier.

Acknowledgments

The collection of the data presented here was made possible, in part, by grant 1 R15 MH65249-01A2 from the National Institutes of Mental Health. Both the collection of data, analysis, and preparation of the report were made possible by a Ramón y Cajal fellowship (RYC2005-447) awarded to the first author, which was funded in part by the Fondo Social Europeo. Preparation of the manuscript was supported by grant IT-276-07 from the Basque Ministry of Science and PSI2008-00412/PSIC from the Spanish Ministry of Science and Innovation.

References

- Bouton, ME. Context and retrieval in extinction and in other examples of interference in simple associative learning. In: Dachowski, L.; Flaherty, CF., editors. *Current topics in animal learning: Brain, emotion, and cognition*. Hillsdale, NJ: Lawrence Erlbaum; 1991. p. 25-53.
- Bouton ME. Context, time, and memory retrieval in the interference paradigms of Pavlovian learning. *Psychological Bulletin*. 1993; 114:80–99. [PubMed: 8346330]
- Bouton ME, King DA. Contextual control of the extinction of conditioned fear: Tests for the associative value of the context. *Journal of Experimental Psychology: Animal Behavior Processes*. 1983; 9:248–265. [PubMed: 6886630]
- Bouton, ME.; Nelson, JB. The role of context in classical conditioning: Some implications for cognitive behavior therapy. In: O'Donohue, W., editor. *Learning and behavior therapy*. Needham Heights, MA: Allyn & Bacon; 1998. p. 59-84.
- Havermans RC, Keuker J, Lataster T, Jansen A. Contextual control of extinguished conditioned performance in humans. *Learning and Motivation*. 2005; 36:1–19.
- Kutlu MG, Schmajuk N. Deactivation and reactivation of the inhibitory power of a conditioned inhibitor: Testing the predictions of an attentional-associative model. *Learning & Behavior*. 2012; 40:83–97. [PubMed: 21915641]
- Larrauri JA, Schmajuk NA. Attentional, associative, and configural mechanisms in extinction. *Psychological Review*. 2008; 115:640–676. [PubMed: 18729595]
- Nelson JB, Bouton ME. The effects of a context switch following serial and simultaneous feature-negative discriminations. *Learning and Motivation*. 1997; 28:56–84.
- Nelson, JB.; Bouton, ME. Extinction, inhibition, and emotional intelligence. In: Feldman-Barrett, L.; Salovey, P., editors. *The Wisdom in Feeling: Psychological Processes in Emotional Intelligence*. New York: Guilford Press; 2002. p. 60-85.
- Nelson JB, Sanjuan MC. A context-specific latent-inhibition effect in a human conditioned-suppression task. *The Quarterly Journal of Experimental Psychology*. 2006; 59:1003–1020. [PubMed: 16885140]
- Nelson JB, Sanjuan MC. Flattening generalization gradients, context, and perceptual learning. *Learning & Behavior*. 2008; 36:279–289. [PubMed: 18927051]
- Nelson JB, Sanjuan MC, Vadillo-Ruiz S, Pérez J, Leon SP. Experimental renewal in human participants. *Journal of Experimental Psychology: Animal Behavior Processes*. 2011; 37:58–70. [PubMed: 20822294]
- Pineño O, Miller RR. Signaling a change in cue-outcome relations in human associative learning. *Learning & Behavior*. 2004; 32:360–375.
- Polack CW, Laborda MA, Miller RR. extinction context as a conditioned inhibitor. *Learning & Behavior*. 2012; 40:24–33. [PubMed: 21786176]
- Rescorla RA. Pavlovian conditioned inhibition. *Psychological Bulletin*. 1969; 72:77–94.
- Rescorla RA. Within-subject renewal in sign tracking. *The Quarterly Journal of Experimental Psychology*. 2008; 61:1793–1802. [PubMed: 18609366]
- Schmajuk NA, Lam YW, Gray JA. Latent inhibition: A neural network approach. *Journal of Experimental Psychology: Animal Behavior Processes*. 1996; 22(3):321–349. [PubMed: 8691162]
- Satterthwaite FE. An approximate distribution of the estimates of variance components. *Biometrics Bulletin*. 1946; 2:110–114. [PubMed: 20287815]
- Welch BL. The significance of the difference between two means when the population variances are unequal. *Biometrika*. 1938; 34:29–35.

Highlights

- > Participants acquired behavioral suppression given a particular signal in a video game.
- > After extinction, suppression to the signal renewed in the conditioning context.
- > Re-testing in the extinction context led to less recovery than in a neutral context.
- > Extinction contexts partially enable extinction performance
- > Partial changes in the meaning of stimuli accompany context changes.

Figure 1.

Suppression to the sensor CS during conditioning in Context A, extinction in Context B, the recovery test in Context A, and the final test in Contexts A, B, or C. Bars represent the standard error of the mean. To avoid clutter, error bars are presented on trials involved in comparisons relevant to the main conclusions.