Appetitive conditioning is not context specific when learned during extinction.

Journal:	*Learning & Behavior*
Manuscript ID:	LB-OR-09-094
Manuscript Type:	Original
Date Submitted by the Author:	17-Dec-2009
Complete List of Authors:	Nelson, James; University of the Basque Country, Basic Processes in Psychology; Home, HomeLombas, Sebastian; Univeristy of the Basque Country, PsicologicaLeon, Samuel; University of Jaen, Psychology
Keywords:	associative learning, context, attention, extinction, renewal

RUNNING HEAD: EXTINCTION AND CONTEXT SPECIFICTY

Appetitive conditioning is not context specific when learned during extinction.

James Byron Nelson[1]

[1]University of the Basque Country

Sebastián Lombas[2]

[2]University of the Basque Country

Samuel P.Léon[3]

[3]University of Jaén

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
34 943 001 5223

Abstract

Two experiments with rats used an appetitive conditioning method to investigate the generality of a hypothesis offered by Rosas and Callejas-Aguilera (2006; 2007). According to that hypothesis, extinction of a CS should arouse attention to contextual cues, resulting in all learning in that context becoming context specific. In Experiment 1 rats received appetitive conditioning with flashing LEDs followed by conditioning with a tone. Conditioning with the tone took place either while extinction of the flasher occurred (Group With Extinction) or not (Group No Extinction). All rats were tested in a different context with the tone. Contrary to the hypothesis, conditioned responding in the different context was greater in Group With Extinction. Experiment 2 replicated Experiment 1's design and included groups that received testing in the same context as conditioning. When tested in a different context, there was, again, generally better responding in Group With Extinction than in Group No Extinction. When tested in the same context, there was generally lower responding in Group With Extinction than in Group No Extinction. Results are discussed in terms of the challenges they pose for the revised retrieval theory presented by Rosas, Callejas-Aguilera, Ramos-Álvarez, and Abad (2006).

Appetitive conditioning is not context specific when learned during extinction.

The term “Renewal” generally refers to the recovery of an extinguished conditioned response as the result of a change in the background context where extinction took place. A classic example is one provided by Bouton and King (1983) where rats received tone-shock pairings in one particular Skinner box designated as Context A. Then, the animals were divided into two groups where one group received extinction with the tone in Context A, and the other group received extinction with the tone in Context B, a different, but equally familiar, context. Following extinction, both groups received a test with the tone in Context A. The animals that had received extinction there continued to show little conditioned responding, performance consistent with that at the end of extinction. Animals that received extinction in Context B showed a robust recovery of the conditioned response (i.e., suppression in this case). Recovery of a learned response that has been changed by further learning is not limited to the design above where conditioning occurred in Context A, extinction in Context B, and testing in Context A (i.e., an ABA renewal paradigm). It can be observed in AAB and ABC paradigms as well (e.g., Rescorla, 2008). The critical variable for observing recovery is that there is a change in the context between the second phase and the test.

The effect is one of wide relevance to learning theory, and psychology in general. It is connected to the “interference” effects found in the learning area (e.g., Bouton, 1991), occasion setting (e.g., Bouton & Nelson, 1994; Nelson & Bouton, 1997), and it bears significant similarity to demonstrations of the encoding-specificity principles found in human memory research (e.g., Tulving & Osler, 1968). The effect is an excellent example of basic research with applied relevance in that it has been suggested as a model of some forms of clinical relapse (e.g., Bouton & Swartzentruber, 1991), stimulating many experimental demonstrations of the context specificity of exposure-based treatments (e.g., Mineka, Mystkowski, Hladek, & Rodriguez 1999; Mystkowski, Craske, & Echiverri ,2002). Thus, any explanation of the effect should not be considered as a mini-theory designed to account for some fluctuation in an otherwise stable data pattern. Rather, any explanation for the effect would be one of general relevance and importance.

To explain the effect Bouton (1993) described it in familiar terms found in associative learning. First, it was assumed that initial excitatory conditioning lead to the development of an excitatory association between the relevant events, a CS and a US in this case (see link 1, Figure 1). During the extinction experience, inhibition (e.g., Wagner, 1981) was assumed to form between the CS and the US, allowing the initial excitatory learning to remain intact. This second-learned inhibition was assumed to be contextually controlled as if input from the CS and the context (links 2.1 & 2.2 in Figure 1) converged on an intermediate “AND” gate (Estes, 1976) which, in turn, activated the inhibition (link 2.3) leading to suppression of the conditioned response. This mechanism provided a powerful heuristic in describing the effect, but begged the question as to why the inhibition learned in the second phase should be coded as context specific.

One answer to that question came from two inclusive proposals by Bouton (1993). First, he proposed that inhibition, such as that learned during extinction, is context specific. Second, he proposed that contexts become important when a previously learned-about stimulus acquired a new meaning. Of these two proposals, there has been little empirical support for the first. Nelson (2002), Nelson and Bouton (1997) and Bouton and Nelson (1994) have demonstrated that inhibition conditioned to a stimulus (e.g., that conditioned to T in an L+/TL- conditioned inhibition design) transfers without observable loss across contexts, at least in appetitive conditioning with rats. There has been support for the second idea. Nelson (2002; 2009) has demonstrated that even simple excitatory learning, which is relatively insensitive to changes in the background context (see Bouton, 1991 for examples) becomes more context specific when such learning is the second association acquired to the stimulus. When a tone had become inhibitory as the result of Pavlovian conditioned-inhibition training prior to T➔Food pairings, animals responded much less to T when it was presented in a new, but equally familiar, context. Rats that had not received the initial inhibitory conditioning with the tone showed no such loss. Learning characterized as either excitatory or inhibitory was shown to be more context dependent when it was the second type of information conditioned to a stimulus.

A key variable that appears to be involved in the acquisition of control by the context when a stimulus acquires multiple associations is whether or not the newly acquired association interferes with previously learned ones. In a predictive learning paradigm with humans Nelson and Callejas-Aguilera (2007) presented participants trials on a computer where particular cues (e.g., products for treating a garden) were paired with particular outcomes (e.g., bug infestation, weeds growing) within contexts provided by different plant nurseries. When a cue was associated with only one outcome, it transferred to another context without loss. When a cue was first associated with one outcome (e.g., the “gold protector” leads to a “bug infestation”), but later associated with two non-interfering outcomes simultaneously (e.g., the “gold protector” leads to both a “bug infestation” and “weeds growing”), knowledge about both outcomes transferred without observable loss to a new context. Even though the relationship between the cue and “weeds growing” was the second thing learned about the cue, it did not appear to be particularly context specific. For other participants the trials were arranged so that the learning in the second phase did interfere with that in the first. After learning an association between the cue and the first outcome, the first outcome was eliminated in the second phase so that learning about the cue and the second outcome interfered with what was learned in the first phase. In these participants, performance associated with learning in the second phase was highly context specific. Simply acquiring a second-learned association did not appear to be sufficient for engaging a contextual control mechanism. Rather, it appeared as though interference was necessary.

While important variables necessary for inducing contextual control have been indentified, the question as to why interference matters is still unanswered. Darby and Pearce (1995) have shown that, in terms of Pearce's (1987, 1994) configural model, contextual stimuli are largely ignored. Pearce assumes that during conditioning a set of stimuli are attended to, and enter into a configural cue which is then associated with the US. Responding to stimuli depends upon their similarity to that configural cue. Thus, when a CS is conditioned in a context, and there is little attention directed to the context, the configural cue that is ultimately associated with the US would consist mostly of those elements available in the CS and it would transfer to another context without loss of conditioned responding. Should attention be directed toward contextual cues, then they would enter into configural cues with the CSs and responding to the cue formed by the CS and a new context would be less than in the original.

Darby and Pearce (1995) suggested that when contexts are important by bearing a discriminative relationship to events embedded within them, then attention is directed to the contexts and they enter into configural cues with CSs. They also suggested that simple extinction may be enough to arouse attention to the context, which would then provide a possible explanation for some examples or response recovery with a context change. If we apply the logic to the experiment of Bouton and King (1983), little attention would be aroused to the context during the first phase of training, thus conditioning would accrue to the tone only. When presented in Context B, no loss of conditioned responding would be expected, paralleling the result Bouton and King observed. When extinction began, the surprise generated by the omission of the expected US would have aroused attention to the context and inhibition would have accrued not to the tone, but to a configural cue generated by the tone and the context. The portion of the inhibitory configural cue contributed by the extinction context would be absent when the tone was presented outside the extinction context, and a recovery of conditioned responding would be expected.

Although the idea presented by Darby and Pearce (1995) provides a mechanism by which contextual information becomes incorporated into learning, it does little to advance our understanding of why the extinction experience leads to a different encoding strategy. There was no principled reason offered for why attention should be aroused by surprise evoked by the omission of the US during extinction, but not by surprise elicited by the unexpected presence of the US early in conditioning. Like Bouton (1993), a different encoding process was simply assumed to be engaged. The idea presented by Darby and Pearce was different from that offered by Bouton in that it assumed that the context and CS enter into a configural cue rather than into an "and gate" type of structure. While the mechanism put forth by Darby and Pearce might explain some instances of a response recovery with a context change after renewal, it cannot capture one of the essential features of the renewal effect. Renewal occurs in the absence of demonstrable context-US associations.

Renewal occurs in a way that is different from the context acting as a simple CS. To illustrate, we can refer again to the work of Bouton and King (1983). Initial fear conditioning to a tone transferred, without loss, to another context. The performance of the rats during extinction in Context A and B was indistinguishable. Thus, the performance elicited by the CS cannot easily be attributed to either summation between the CS and any Context-US associations or a Test Context-CS configural cue. When the groups were tested in Context A, a renewal of responding was nevertheless observed in the group that had received extinction in Context B. That recovery could be the result of losing inhibition conditioned to either the extinction context, or to an extinction context-CS configural cue as would occur in a Pearce (1994)-type mechanism.

In those experiments, rats also received pairings of a Light with the US and were then tested with the light in extinction in Context B. For one group of rats this was the context where the tone had been extinguished and the context could be inhibitory by way of a direct association with the US, or generalization from an inhibitory Context-CS configural cue. For another group, the tone was extinguished in Context A, thus context B was associatively neutral. Despite the inhibitory potential for Context B in the group that had received extinction there, the groups did not differ in their extinction to the Light. That is, there was no evidence that the extinction context was inhibitory (see also Bouton &

Swartzentruber, 1986). The control exhibited by the extinction context appeared much more specific than would be predicted by Pearce's configural theory (Pearce, 1987; 1994).

Bouton (1997) restated the idea offered by Darby and Pearce (1995) of contextual control resulting from attention being directed to the context during extinction in slightly different terms. Rather than suggest that the context enter into a configural cue as did Darby and Pearce (1995), he suggested that the result of such attention was the incorporation of contextual input into the "and" gate structure of Figure 1. Rosas and Callejas-Aguilera (2006) have recently revisited that idea and extended it. In line with both Bouton and Darby and Pearce, Rosas and Callejas-Aguilera suggested that when a stimulus becomes ambiguous, such as when it undergoes extinction and can potentially control two different associations, attention is aroused to the context. As a result, they suggest that all information learned in that context, not just that which produces the ambiguity, would become context specific. Evidence for that hypothesis came from experiments that used a predictive learning task where participants associated particular food cues with outcomes such as gastric malaise in the context of particular restaurants. When food cues consistently predicted the same outcomes, they transferred well to new contexts. However, if an outcome was changed between phases for one food cue, producing interference and making the cue ambiguous, information about other food cues that had not changed became context specific.

The effect Rosas and Callejas-Aguilera (2006a) observed was robust, and occurred between counterbalanced experimental methods. For example, in one task participants learned food-outcome relationships where a cue (X) was paired with one outcome, such as diarrhea, (O1) in the first phase, and a different outcome (O2) in the second. As a result of the pairings with the new outcome (e.g., extinction of X-O1) learning about another cue which maintained a consistent relationship with 01 became context specific. After that training and testing, the participants were asked to participate in a second experiment. Here, they were asked to learn about the relationship between garden products and flower growth. In this task, simple cue-outcome relationships were also context specific, but only if extinction had been involved in the first task. Learning conflicting information about a cue aroused a process leading to the incorporation of context into learning that maintained across different (but similar) experimental tasks.

Rosas and Callejas-Aguilera (2006) results appear well established within their methodology (see also Nelson & Callejas-Aguilera, 2007; Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad , 2006). Work on this question with animals, on the other hand, currently consists of one brief report. With rats, Rosas and Callejas-Aguilera (2007) trained one group of rats in a taste aversion procedure where flavor X was paired with lithium-chloride induced illness in Context A. In the second phase, the aversion to X was extinguished. After the aversion to X was extinguished, a new flavor Y was conditioned. A control group received the same training, except that in phase 1, X and the lithium-chloride induced illness were not paired. Thus, in phase 2, X did not undergo extinction when presented. When tested between-subjects in Context A or in Context B, there was a loss of the aversion to Y with the context change in the group where X had undergone extinction. Such a loss was not evident in the groups where X did not undergo extinction.

While promising, we are cautious with these results. Though not always the case (e.g., Rosas & Bouton, 1997; 1998) taste aversion learning has been shown to sometimes be context specific (see Archer, Sjödén & Nilsson, 1985; Sjödén & Archer, 1989, Bonardi, Honey, & Hall, 1990). Thus, one could argue that something about Rosas's unpaired control treatment reduced context specificity that they could have ordinarily observed, rather than to say that the experimental treatment produced it. Also, though not analyzed, there appeared to be less responding in Context A in the control group than in the experimental group, reducing the range in which to observe an effect. Finally, Rosas and Callejas-Aguilera's analysis strategy did not directly assess the effect of their between-group extinction manipulation. They demonstrated a context-effect in groups that had experienced extinction, but not the other others, as opposed to showing that extinction had an effect when testing was in a different context, and none when testing was in the same context. The goal of the present experiments was to determine whether extinction of one stimulus would lead to the context-specificity of another in rats using a conditioning preparation where conditioned responding has been shown to transfer well across contexts (e.g., Brooks & Bouton, 1994; Nelson, 2002; Nelson & Bouton, 1997).

Experiment 1

In Experiment 1 two groups of rats received appetitive conditioning with a flashing light-emitting-diode (LED) stimulus. Then, they were divided into two groups that received conditioning with a tone. In Group With Extinction, the tone was conditioned during sessions where the flashing-LED stimulus was presented without the US. In Group No Extinction, the tone was conditioned during sessions with no other events occurring. Finally, both groups were tested in Context B. Context B was an equally familiar context that was equally associated with the food US. If extinction leads to attention to the context, leading to all information being encoded as context specific, then there should be less responding to the tone in Context B in Group With Extinction than in Group No Extinction.

Method

Subjects

Sixteen male Wistar rats with an average weight of 349 grams were used in the first experiment. Rats were housed in stainless-steel hanging cages on a 12-12 light-dark cycle. The experiment was conducted in the light part of the cycle. Water was available ad lib. Access to food was restricted as described below. These rats had previously served in a taste aversion experiment in their home cages that did not involve extinction.

Apparatus

All experimental equipment was contained in sound attenuation chambers. The inside of each chamber was square (W = H = 54 cm) and the chamber was 39 cm deep. A 12.5-cm 8-ohm speaker was mounted on the right wall at a height of 34 cm and 18 cm from the rear wall. A 12-v light was mounted in the ceiling of the chamber in a 12 cm x 6 cm x 3 cm (L x W x H) plastic diffusing prism. The prism was mounted with the length parallel to the rear wall, 18 cm from the rear wall and 10 cm from the right wall. A 7.5 cm square ventilation fan was mounted in the lower left corner of each chamber that provided 60db of background noise.

Subjects were run in eight standard operant testing boxes (MED Associates ENV-007). Each box was placed in an attenuation chamber 18 cm from the right wall and 8 cm from the rear wall so that the right panel of the boxes, which contained visual light stimuli, was shadowed.

The front, back, and top of each 30.5-cm x 24.1-cm x 29.2-cm (L x W x H) box was plexiglass with the right and left walls constructed of aluminum with grid floors. Bars in the floor were 3 mm spaced 1 cm apart. The right wall of each box contained non-auditory stimuli. A food delivery magazine with a 5 x 5 – cm square opening and a depth of 4 cm was centered from left to right in the wall and mounted so that the food trough was 5 cm above the grid floor. A photocell was mounted 1 mm above the trough at a depth of 1 cm. Two white 28-v keylights (2.5 cm diameter) were mounted 18 cm above the grid floor and 7 cm horizontally to the left and right of the center of the wall. Four-cm above the food magazine three 5-mm LEDs were mounted, with the second centered in the wall from left to right and the other two mounted 1 cm to the left or right of the center. The leftmost LED was red, the center yellow, and the rightmost LED was green.

When delivered, the tone stimulus (T) was an 80db 3000hz tone through the speaker. The illumination of the keylight mounted to the left of the foodcup served as stimulus L. Each LED was illuminated in turn from left to right in a flashing sequence. For example, the first LED was illuminated for 20 ms producing a flash. As that LED was turned off, the middle LED was flashed on and so forth with the illumination of the leftmost LED following that of the rightmost LED. This flashing sequence of LEDs served as stimulus F. All stimuli were 10 s in duration. When delivered, the unconditioned stimulus (US) was the delivery of two 45-mg pellets (PJ Noyes traditional formula), immediately on termination of the conditioned stimulus.

The eight operant boxes were divided into two sets of four to serve as Contexts A and B and were always completely counterbalanced. One set of boxes had a laminated solid-white sheet of paper located behind the rear plexiglass wall so that it appeared uniformly white. The bars in the floor of these boxes were mounted parallel to each other at the same height. The other set of four boxes differed from the first in visual and tactile respects. The sheet of paper mounted outside the rear wall had a checkerboard pattern with 2.5 – cm black and white squares. The grid floor consisted of staggered grids with odd-numbered grids mounted 1 cm above the even numbered grids.

All events were controlled by a Pentium (IBM compatible) computer programmed in Pascal.

Procedure

Rats were food deprived over one week to 80% of their free-feeding weight and maintained at that weight throughout the experiment. On the first day of training the rats were placed in both sets of boxes for 30 min in each session. During the first 15 minutes they were allowed to explore the chambers with no events occurring. During the last 15 minutes 20 single food pellets were delivered with a variable 45-s schedule to train the rat to eat from the food cup at the sound of a pellet delivery.

All rats received two 60-min sessions of training each day for the remainder of the experiment. Throughout the experiment, excluding the test days, there was one session in Context A and one in Context B to equate familiarity with the two contexts. Every session in B contained a pairing of L with the US at the same time into the session as the US occurred in the corresponding session in Context A. The order of exposure was ABAB or BABA varying daily with the restriction that each experimental phase began in Context A. There were two phases of training and a test.

Phase 1: Excitatory conditioning of F. Each daily session of Phase 1 in Context A contained 10 pairings of F with the US with an inter-trial interval (ITI) varying randomly around a mean of 350 s. There were six days of training in the first excitatory conditioning phase.

Phase 2: Excitatory conditioning with or without extinction. The rats were divided into two groups by matching them on their performance to F in the previous phase. Over the next three days rats in Group With Extinction received five trials with F presented without the US and five trials with T paired with the US in each daily session. The first session began with three presentations of F. The sequence for the remainder of the trials and remaining sessions was randomly determined with the restriction that no more than two trials of a type occurred together. The ITIs were randomly determined with an average of 350 seconds. Rats in Group No Extinction received the same T+ trials, distributed across the session in the same way as those in Group With Extinction, but there were no stimuli presented on trials where F would have occurred in Group With Extinction.

Testing. Following the last day of the second phase both groups of rats received two consecutive sessions of testing in Context B with the tone. There were 10 presentations of the tone in extinction using the same ITI schedule as was used in the previous phase.

Data and analysis

A computer recorded the number of times the photocell in the foodcup was interrupted during the 10-s CSs and during the 10-s immediately prior to the CS (pre-CS). All data were analyzed with mixed-factorial analysis of variance (ANOVA) with Type III sums of squares. Simple effects were conducted using ANOVA with error terms appropriately derived from the overall analysis using standard methods (see Howell, 1987). Degrees of freedom for simple effects were reduced using the Welch (1938) – Satterthwaite (1946) procedure to compensate for the pooling of potentially heterogeneous variances. Analyses of the number of trials where one group outperformed another on the test were analyzed with binomial tests.

In the analysis of responding in the CS, effect sizes were computed for the overall ANOVAs using partial eta squred (η_p^2). For analyses on the test that involved only two means Cohen's *d* $\left(\overline{X}1 - \overline{X}2 \big/ \sqrt{S^2_{pooled}}\right)$ was calculated using the respective variances of the variables being compared. Throughout, a rejection criterion of $p < .05$ was adopted though exact probabilities were reported to provide a full characterization of the results.

Results

Phase 1: Excitatory conditioning of F

The six sessions of conditioning with F were analyzed with a Group x Session ANOVA which showed a reliable effect of Session, $F(5,70) = 10.81$, $p < .001$, $\eta_p^2 = .44$, and no effects of Group or interaction, Fs < 1. The data are shown in the left of Figure 1, which collapses across the insignificant Group variable for simplicity. The same analysis of pre-CS responding showed an effect of Session, $F(5,70) = 8.62$, $p < .001$, as pre-CS responding decreased from a mean of 2 to a mean of .80 over the sessions.

Phase 2: Conditioning of T with or without extinction of F

Extinction of F. During the phase where T was conditioned, responding to F reliably decreased both within and across sessions in Group With Extinction. A Trials by Session analysis showed an effect of Session , $F(2,56) = 5.97$, $p = .01$, $\eta_p^2 = .46$, Trials, $F(4,56) = 8.67$, $p < .01$, $\eta_p^2 = .55$, and a marginal Trials by Session interaction, $F(8,56) = 2.10$, $p = .051$. These data are shown in Figure 1 as the triangles above “T+ / - or F- “ on the abscissa, collapsed across trials. The same analysis of pre-CS responding showed no effects, $F\text{s} \leq 1.09$, $p\text{s} \geq .38$. Pre-CS responding before F trials averaged .57.

Conditioning of T. Responding to T in the two groups was analyzed with a Group x Trials x Session ANOVA. There were effects of Trials, $F(4,56) = 17.46$, $p < .001$, $\eta_p^2 = .55$, and Session, $F(2,28) = 38.55$, $p < .001$, $\eta_p^2 = .73$, but no other effects, $F\text{s} \leq 1.62$, $p\text{s} \geq .61$. These data are shown in Figure 1 as the circles (Group With Extinction) and squares (Group No Extinction) above “T+ / - or F- “ on the abscissa, collapsed across trials. The same analysis of pre-CS responding showed an effect of Trials, $F(4,56) = 2.78$, $p = .03$, $\eta_p^2 = .16$, as responding tended to decrease slightly from the first trial (average = .9) to the last trial (average = .36) collapsed across sessions. There were no other effects, $Fs \leq 1.27$, $ps \geq .26$.

Test.

On the test, Group With Extinction responded numerically more than Group No Extinction on 18 of the 20 test trials, an overall pattern which was very reliable (*binomial* $p < .001$). During the pre-CS the groups responded the same (mean = 0) on five of the 20 trials. On the remaining 15, there was a trend for Group With Extinction to responded numerically less than Group No Extinction on 10 of the 15 remaining trials, a pattern which was not reliable (*binomial* $p = .092$).

Further analysis with a Group x Trials ANOVA of the first session showed a main effect of Group, $F(1,14) = 6.36$, $p = .02$, d =1.26, Trials, $F(9,126) = 8.16$, $p < .001$, η_p^2 =.37, and no interaction, $F < 1$. A Group x Trials ANOVA of the second session mirrored the first with effects of Group $F(1,14) = 4.75$, $p = .047$, d = 1.06, and Trials, $F(9,126) = 6.81$, $p < .001$, η_p^2 =.33, but there was an interaction, $F(9,126) = 2.33$, $p = .02$, η_p^2 = .14. Simple effects of Group on each trial showed reliable differences on Trials 2 and 9, $Fs(1,91) \geq 4.41$, $ps < .038$, $ds \geq .92$.

The same ANOVAs applied to the pre-CS data found no effects, $Fs \leq 1.47$, $ps \geq .16$.

Discussion

Experiment one sought to determine whether the hypothesis and findings put forth by Rosas and Callejas-Aguilera (2006) would hold in an appetitive conditioning method with rats. After receiving conditioning of T either while another CS was undergoing extinction or not, all rats were tested for context-specificity of responding to T in another context. Contrary to the hypothesis that extinction should arouse attention to the context and cause all learning to become context specific, the opposite pattern of results was obtained. When conditioning with T occurred concurrently with extinction of F, better transfer to a new context was observed than if conditioning of T occurred alone.

"Surprise" should have been produced during each session of conditioning with T in Group With Extinction. The analysis of the extinction of F showed that there were effects of *Session* as responding decreased between sessions, and there was an effect of *Trials*, as responding decreased within each session. The *Trials by Session* interaction was just short of being reliable, which suggests that although the effect of trials may have gotten smaller on each session as extinction progressed, extinction was evident in all three sessions of training with T. Performance to T changed over sessions, thus it should have been ambiguous in meaning. According to both Rosas and Callejas-Aguilera (2006) and Darby and Pearce (1995) attention should have been present within each session, ensuring that the conditioning to T was context specific producing a decrement in responding with a context change.

It is possible, though unlikely, that the groups differed in their level of conditioning to T. The analysis of the conditioning data showed no differences between the groups on any trial of any session, across a range of responding. Nevertheless, the test in extinction could have been a more sensitive test of group differences in responding to T. Thus, we conducted a second experiment that replicated the two groups presented here and included two more that were treated identically, but tested with T in extinction in Context A.

Experiment 2

Experiment 2 replicated the design of Experiment 1 but included two additional groups that received testing in Context A. The design was a two by two factorial combining whether or not conditioning of T occurred concurrently with extinction of F, and whether testing was conducted in the training context (Context A) or a different one (Context B). Based on the previous study, we expected that responding to T would transfer very well to Context B in the group where it was conditioned concurrently with extinction of F. In Context A, we expected that responding would not differ between the groups during the extinction test.

Method

Subjects

32 male Wistar rats with an average weight of 367 grams were used in this experiment. As in the previous study, these animals had been involved in a taste aversion study in their home cages (extinction was not involved).

Apparatus

The same apparatus as was used in the first experiment was used here.

Procedure

All rats received the same training in the first phase as in the first experiment. Then, two groups of rats (With Extinction, No Extinction) were formed matched on their session means of responding to F. In Phase 2, rats in Group With Extinction and No Extinction received the same treatment as did their corresponding conditions in the first experiment. Each group was then subdivided into two matched groups (based on session means of responding to T) for testing in Context A or Context B (i.e., With Extinction, Test A and With Extinction, Test B). The test procedure was identical to the previous experiment with the exception that the test context was Context A for those rats tested there.

An apparatus failure on day two of the first phase corrupted one squad of rats, leaving only six rats per condition. Having extensive experience with this method, we knew that that number would be too small to reliably detect any but the largest of effects thus we immediately replicated the study with 32 more rats with the same characteristics as those in this study (average weight – 375g), raising the overall n per condition to 14.

Results

Phase 1: Conditioning with F

The six sessions of conditioning with F were analyzed with an Extinction (with or without) x Test Context x Session ANOVA which showed a reliable effect of Session, $F(5,260) = 12.64$, $p < .001$, $\eta_p^2 = .19$, and no other effects or interactions, Fs ≤ 1.13, ps $\geq .57$. The data are shown in the left of Figure 2, which collapses across the insignificant grouping variables. The same analysis of pre-CS responding showed an effect of Trials, $F(5,260) = 16.05$, $p < .001$, as pre-CS responding decreased from a mean of 2.05 to a mean of .72 over the sessions. There were no other effects in the pre-CS analysis, Fs ≤ 1.4, ps $\geq .22$.

Phase 2: Conditioning of T with or without extinction of F

Extinction of F. Extinction trials with F were analyzed with a Test Context by Trials by Session ANOVA. The analysis revealed effects of Trials, $F(4,104) = 2.68$, $p = .035$, $\eta_p^2 = .09$, Session, $F(2,52) = 10.52$, $p < .001$, $\eta_p^2 = .29$, and a Trials by Session interaction, $F(8,208) = 3.71$, $p < .001$, $\eta_p^2 = .13$. Responding tended to decrease across trials in Session 1, perhaps show some spontaneous recovery in Session 2 with little change in response across trials, and decreased across trials again in Session 3. No other effects were reliable, Fs ≤ 1.30, ps $\geq .27$. These data are shown in Figure 2 as the triangles above “T+ / - or F- “ on the abscissa, collapsed across the trials.

The same analysis of pre-CS responding showed a session by trials interaction, F(8,208) = 2.13, p = .03. The interaction was due to variability among the trials in the first session, (minimum = .21 on trial 2, maximum = 1.1 on trial 3) and second session (minimum = .18 on trial 2, maximum = 1.32 on trial 4) that was absent by the third session (minimum = .32 on trial 2, maximum = .57 on trial 3).

Conditioning trials with T were analyzed with an Extinction by Test Context by Trials by Session ANOVA. The analysis revealed effects of Session, $F(2,104) = 42.22$, $p < .001$, $\eta_p^2 = .45$, Trials, $F(4,208) = 49.35$, $p < .001$, .49, and a Session by Trials interaction, $F(8,416) = 5.26$, $p < .001$, $\eta_p^2 = .098$. There were effects of Trials within each session, *F*s(4,622) = 20.37, 28.2, and 15.30, for Sessions 1, 2 and 3, respectively. The effect of trials was simply more pronounced in the first session and smaller by the third session. These data are shown in Figure 1 as the circles (Group With Extinction) and squares (Group No Extinction) above “T+ / - or F- “ on the abscissa, collapsed across trials.

There were no other reliable effects, though the Session by Trials by Context interaction approached significance, $F(8,416) = 1.76$, $p = .08$. The groups were formed by matching on the session means. The matching did not consider the distribution of the trials within each session, yet inspection of the data did not reveal any obvious patterns that would suggest a Trials by Context interaction. Because any pre-existing difference here would be important on the test, we nevertheless conducted simple effect tests of Context on each trial of each session, and failed to find any reliable differences, *F*s < 1.

The same analysis of pre-CS responding before T trials revealed an Extinction by Session interaction, $F(2,104) = 4.90$, $p = .009$. On the first session responding appeared lower in the groups receiving extinction of F (mean = .46) than in the other condition (mean = 1.26), $F(1,145) = 8.96$, $p = .004$. The differences were more negligible, and unreliable, *F*s < 1, on the last two sessions (Session 2 means = .8 and .82 for Group With Extinction and No Extinction, respectively. Session 3 means = .82 and .68 for Group With Extinction and No Extinction, respectively.) We will have more to say about these differences in the discussion.

Test

As in the first experiment, when tested in Context B rats that received conditioning of T concurrent with extinction of F responded at a numerically higher rate on the majority of the trials (15 of 20) than those that simple received conditioning of T (*binomial p* = .01). In Context A, the pattern was reversed. Rats that received conditioning of T concurrent with extinction of F responded numerically less on the majority of trials than those that simply received conditioning of T on 16 of 20 trials (*binomial p* = .005). However, none of these differences were as large as in the previous experiment.

During the pre-CS, rats in Group With Extinction responded numerically more than rats in the other condition on 9 of 20 trials in Context B, and 11 of 20 trials in Context A, and neither pattern was reliable, (*binomial p*s = .116).

The first session was further analyzed with an Extinction by Context by Trials ANVOA. The analysis revealed an effect of Trials, $F(9,468) = 15.23$, $p < .001$, η_p^2 =.23 and an Extinction by Context by Trials interaction, $F(9,468) = 2.18$, $p = .02$, η_p^2 =.04. There were no other effects, *F*s < 1. The analysis was a rare case where the interaction test had more power than the direct simple-effect tests. There was no detectable effect of the extinction manipulation in either test context. When tested in Context B there was a trend for responding on trial 1 in Group No Extinction to be higher than in Group Extinction, $F(1,253) = 3.37$, $p = .068$, but nothing else was close in either context $F\text{s} \leq 1.5$, $p\text{s} \geq .22$. We further examined the interaction by comparing the difference obtained between the two extinction groups in each context ((With Extinction, Context B minus Without Extinction, Context B) vs (With Extinction, Context A minus No Extinction, Context A)) on each trial. That is, we investigated Extinction by Context interactions on each trial. We found that the pattern produced by the Extinction manipulation in Context B was significantly opposite that produced in Context A on trials 1, 3, and 4, $F\text{s}(1,253) \geq 4.4$, $p\text{s} \leq .037$, and it approached significance on trial 7, $F(1,253) = 3.37$, $p = .068$.

The same ANOVAs applied to pre-CS responding showed an effect of Trials, $F(9,468) = 2.35$, $p = .01$, and no other effects, $F\text{s} < 1$. Responding decreased from an initial mean of .89 to .39 across the test session.

An Extinction by Context by Trials ANOVA of responding in the CS on the second session produced only an effect of Trials, $F(9,468) = 7.21$, $p < .001$, $\eta^2 = .12$, and no other effects, $F\text{s} \leq 1.88$, $p\text{s} \geq .18$. The same analysis of pre-CS responding on Session 2 found no effects, $F\text{s} < 1$. Pre-CS responding averaged .42 in Session 2 of the test.

Discussion

The design of Experiment two was a two by two factorial combining whether or not conditioning of T occurred concurrently with extinction and whether testing was conducted in Context A or B. The main result replicated Experiment one. That is, there was no evidence of context-specificity of conditioned responding when conditioning was conducted concurrently with extinction. As in the previous experiment, there were effects of trials within each session of conditioning with T, and the animals responding to F changed both between and within sessions in the groups that received extinction. Thus, those trials should have been producing either, or both, surprise and ambiguity throughout the phase, leading to context specificity of conditioning to T according to Rosas and Callejas-Aguilera (2006).

The result obtained in Experiment 1, where responding appeared to transfer better to Context B when conditioning was concurrent with extinction, was only weakly supported. The effect of extinction appeared to have generally opposite effects on responding, depending on the context where testing occurred. On the first trial, the pattern elicited in Context B was opposite of that in Context A. In Context B, concurrent extinction appeared to lead to a reduction in responding, and in Context A it appeared to lead to an increase in responding. While that pattern alone could be consistent with the hypothesis of Rosas and Callejas-Aguilera (2006), the opposite pattern was obtained on trials 3 and 4, and was almost reliable on trial 7. Thus, the overall pattern was more consistent with the results of the previous experiment. The binomial analysis of the directionality of responding was also consistent with the first experiment.

The response rates in this experiment were lower than in the first experiment (and the rats were slightly older). Those lower response rates likely prevented us from robustly replicating the increase in responding in Context B observed in Experiment 1. The general tendency for responding in Context B to be greater when conditioning was conducted concurrently with extinction was nevertheless present. Moreover, that tendency was clearly not present in Context A, where the opposite trend appeared. We can only speculate as to why this unexpected pattern may have occurred. The overall pattern obtained might be explained if the context were to become weakly inhibitory during the second phase in Group With Extinction. The extinction trials with F might produce a small amount of inhibition to the context, which could mildly super-condition T (e.g., Williams & McDevitt, 2002). Such conditioning would be revealed as an increase in responding to T in Context B. Also, the presence of weak inhibition to the context might facilitate extinction in that group when conducted in Context A. The pre-CS analysis of the second phase was consistent with this speculation. On the first session, where the excitatory F began extinction, there was less baseline responding before T trials in Group With Extinction than in Group No Extinction. Though that difference disappeared on later sessions it was nevertheless consistent with the idea that some weak inhibition may have initially conditioned to the context following F- trials in Group With Extinction. Despite the plausibility of this speculation, we should point out that there was no such effect on pre-CS responding in the previous experiment.

In short, we presently do not know what was responsible for the mild increase in responding observed in Context B, but the empirical result provides considerably stronger evidence against the hypothesis assessed by the research than a null result. There was clearly no decrement in conditioned responding to T with a context switch after it was conditioned concurrently with extinction of another CS.

General Discussion

The present experiments were undertaken to assess the generality of the hypothesis offered by Rosas and Callejas-Aguilera (2006). Rosas and Callejas-Aguilera suggested that when a stimulus undergoes extinction, attention to the context is aroused as the stimulus becomes ambiguous. As a result of that attention, all learning that occurs in that context is coded as context specific.

In our experiments, rats received appetitive conditioning of T either while another previously conditioned stimulus, F, was undergoing extinction or not. As might be inferred from the design, we expected that there would be some effect of extinction of F on responding to T in the different context. The design was a confirmatory design in that we expected to see a deleterious effect of a context change on responding to T, or a null result. Rather than a null result, we obtained evidence that disconfirmed the hypothesis. There was no evidence during training that responding to T differed between the groups, and when tested in Context A, there was a trend for T to extinguish more rapidly when it was conditioned concurrently with the extinction of F. When tested in Context B, there was no evidence of context-specific conditioned responding to T. Rather, there was unexpected evidence that responding to T increased in the different context.

The idea put forth by Rosas and Callejas-Aguilera (2006) has undergone some revision (Callejas-Aguilera & Rosas, in press; Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad, 2006) since their initial presentation (Rosas, García-Gutiérrez, & Callejas-Aguilera, 2006). Initially, the theory suggested that attention might engage the context through a modulatory mechanism such as that offered by Bouton (1993), or that the context may act as an occasion setter, or the context could enter into a configural cue such as that proposed by Pearce (1994). Most recently Callejas-Aguilera and Rosas stated that attention could lead to the use of the mechanisms just mentioned, as well as direct context-outcome associations, which we may have observed early in the second phase of Experiment 2.

Considering that their theory is still in development, these results produce important constraints on their theorizing. Our results show that making F ambiguous through extinction did not lead to context-specificity of conditioned responding to T. Some mechanism was engaged, as the context switch tended to increase responding to T when conditioned concurrently with extinction of F. Whether the results we obtained were due to some mild inhibition to the context is speculation, as is whether or not attention to the context (induced by extinction of the flasher) would lead to the development of that type of direct context-outcome association. The theory does not define the conditions under which the supposed attention should promote the operation of one mechanism (e.g., modulation) over another (e.g., context-outcome associations).

We believe that two things must be accomplished for the theory of Rosas and his colleagues to continue to warrant serious merit. First, we believe that empirical work should demonstrate the actual involvement of attention. To date, there has been no independent evidence of attention beyond the effects it is invoked to explain, a point Rosas and Callejas-Aguilera (2006) acknowledge. Second, the most recent exposition of the theory must be refined so that clear a-prior predictions regarding when attention will favor one mechanism of contextual control over another can be determined. Callejas-Aguilera and Rosas (in press) predict an effect of a context change in these experiments, yet without further clarifications the direction of that change cannot be specified. In the absence of that clarification, the present results are at strong odds with the one clear hypothesis offered by the theory that has been demonstrated with humans, challenging the theory’s present usefulness as a general principle.

Acknowledgements

The research and report presented here 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 also supported by grant IT-276-07 from the Basque Ministry of Science and PSI2008-00412/PSIC from the Spanish Ministry of Science and Innovation. Participation in the research by Samuel P. Léon was enabled by projects SEJ2007-67053/PSIC and BES-2008-003634 from the Spanish Ministry of Science and Innovation. The technical and human support provided by SGIker (UPV/EHU, MICINN, GV/EJ, ESF) is gratefully acknowledged.

References

Archer, T., Sjödén, P., & Nilsson, L. (1985). Contextual control of taste aversion conditioning and extinction. In P. D. Balsam & A. Tomie, *Context and learning* (pp. 225–271). Hillsdale, NJ: Erlbaum.

Bonardi, C., Honey, R. C., & Hall, G. (1990). Context specificity of conditioning in flavor-aversion learning: Extinction and blocking tests. *Animal Learning and Behavior*, *18*, 229-237.

Bouton, M. E. (1991). Context and retrieval in extinction and in other examples of interference in simple associative learning. In L. Dachowski & C. F. Flaherty (Eds.), *Current topics in animal learning: Brain, emotion, and cognition* (pp. 25-53). Hillsdale, NJ: Lawrence Erlbaum.

Bouton, M. E. (1993). Context, time, and memory retrieval in the interference paradigms of Pavlovian learning. *Psychological Bulletin, 114*, 80-99.

Bouton, M. E. (1997). Signals for whether versus when an event will occur. In M. E. Bouton & M. S. Fanselow (Eds.) *Learning, motivation and cognition: The functional behaviourism of Robert C. Bolles* (385-409). Washington, DC: American Psychological Association.

Bouton, M. E., & King, D. A. (1983). Contextual control of the extinction of conditioned fear: Tests for the associative value of the context. *Journal of Experimental Psychology: Animal Behavior Processes, 9*, 248-265.

Bouton, M. E., & Nelson, J. B. (1994). Context-specificity of target vs. feature inhibition in a feature-negative discrimination. *Journal of Experimental Psychology: Animal Behavior Processes, 20*, 51-65.

Bouton, M. E., & Swartzentruber, D. (1986). Analysis of the associative and occasion-setting properties of contexts participating in a Pavlovian discrimination. *Journal of Experimental Psychology: Animal Behavior Processes, 12,* 333-350.

Bouton, M. E., & Swartzentruber, D. (1991). Sources of relapse after extinction in Pavlovian and instrumental learning. *Clinical Psychology Review*, *11*, 123-140.

Brooks, D. C., & Bouton, M. E. (1994). A retrieval cue for extinction attenuates response recovery (renewal) caused by a return to the conditioning context. *Journal of Experimental Psychology: Animal Behavior Processes, 20*, 366-379.

Callejas-Aguilera, J. E., & Rosas, J. M. (*in press*) Ambiguity and Context Processing in Human Predictive Learning. *Journal of Experimental Psychology: Animal Behavior Processes*. *In press*.

Darby, R. J., & Pearce, J. M. (1995). Effects of context on responding during a compound stimulus. *Journal of Experimental Psychology: Animal Behavior Processes, 21,* 143-154.

Estes, W. K. (1976). Structural aspects of associative models of memory. In C. N. Cofer (Ed.), *The structure of human memory* (pp. 31–53). New York: Freeman.

Howell, D. C. (1987). *Statistical methods for psychology.* Boston: Duxbury Press.

Mineka, S., Mystkowski, J. L., Hladek, D., & Rodriguez, B. I. (1999). The effects of changing contexts on return of fear following exposure treatment for spider fear. *Journal of Consulting and Clinical Psychology, 67*, 599-604.

Mystkowski, J. L., Craske, M. G., & Echiverri, A. M. (2002). Treatment Context and Return of Fear in Spider Phobia. *Behavior Therapy, 33,* 399-416.

Mystkowski, J. L., Mineka, S., Vernon, L. L., & Zinbarg, R. E. (2003). Changes in Caffeine State Enhance Return of Fear in Spider Phobia. *Journal of Consulting and Clinical Psychology, 71,* 243-250.

Nelson, J. B. (2002). Context specificity of excitation and inhibition in ambiguous stimuli. *Learning and Motivation*, *33*, 284-310.

Nelson, J. B. (2009). Contextual control of first- and second-learned excitation and inhibition in equally ambiguous stimuli. *Learning & Behavior*, *37*, 95-106.

Nelson, J. B., & Bouton, M. E. (1997). The effects of a context switch following serial and simultaneous feature-negative discriminations. *Learning and Motivatio*n, *28*, 56-84.

Nelson, J. B., & Callejas-Aguillera, J.E. (2007). The role of interference produced by conflicting associations in contextual control. *Journal of Experimental Psychology: Animal Behavior Processes. 33*, 314-326

Pearce, J. M. (1994). Similarity and discrimination: A selective review and a connectionist model. *Psychological Review, 101,* 587-607.

Pearce, J. M. (1987). A model for stimulus generalization in Pavlovian conditioning. *Psychological Review*, *94*, 61–73.

Rescorla, R. A. (2008). Within-subject renewal in sign tracking. *The Quarterly Journal of Experimental Psychology*, *61*, 1793-1802.

Rosas, J. M., & Bouton, M. E. (1997). Renewal of conditioned taste aversion upon return to the conditioning context after extinction in another one. *Learning and motivation*, *28*, 216-229.

Rosas, J. M., & Boutoin, M.E. (1998) Context and retention interval can have additive, rather than interactive, effects after taste aversion conditioning. *Psychonomic Bulletin and Review*, *5*, 79-83.

Rosas, J. M., & Callejas-Aguilera, J. E. (2006) Context Switch Effects on Acquisition and Extinction in Human Predictive Learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32(3)*, 461-474.

Rosas, J. M., & Callejas-Aguilera, J. E. (2007) Acquisition of a conditioned taste aversion becomes context dependent when it is learned alter extinction. *Quarterly Journal of Experimental Psychology, 60*, 9-15.

Rosas, J. M., Callejas-Aguilera, J. E., Ramos-Álvarez, M. M., & Abad, M. J. F. (2006) Revision of retrieval theory of forgetting: What does make information context-specific? *International Journal of Psychology and Psychological Therapy, 6*, 147-166.

Rosas, J. M., García-Gutiérrez, A., & Callejas-Aguilera, J. E. (2006). Effects of context change upon retrieval of first and second-learned information in human predictive learning. Psicológica, 27, 35–56.

Satterthwaite, F. E. (1946). An approximate distribution of the estimates of variance components. Biometrics Bulletin, 2, 110–114.

Sjödén, P., & Archer, T. (1989). Taste-aversion conditioning: The role of contextual stimuli. In T. Archer & L. G. Nilsson, Aversion, avoidance, and anxiety perspectives on aversively motivated behavior (pp. 87–120). Hillsdale, NJ: LEA.

Tulving, E., & Osler (1968). Effectiveness of retrieval cues in memory for words. *Journal of Psychology, 77,* 593-601.

Wagner A. R. *(*1981*).* SOP: A model of automatic memory processing in animal behavior*. In* Spear N. E.*,* Miller R. R. *(Eds.), Information processing in animals: Memory mechanisms (pp.* 5-47*).* Hillsdale, NJ*:* Erlbaum*.*

Welch, B. L. (1938). The significance of the difference between two means when the population variances are unequal. *Biometrika, 34,* 29-35.

Williams, B. A., & McDevitt, M.A. (2002). Inhibition and superconditioning. Psychological Science, 13, 454-459.

Figure Captions

Figure 1. Responding during the CS from Experiment 1. Left-most points show session means of responding to F in the first phase, collapsed across groups. Points above “T+ / - or F-“ show session means of responding to T when conditioned alone (squares) or during extinction of F (circles). Triangles show responding to F during extinction. Points above Test T- show the individual trials of each test session in Context B. See text for further details.

Figure 2. Responding during the CS from Experiment 2. Left-most points show session means of responding to F in the first phase, collapsed across groups. Points above “T+ / - or F-“ show session means of responding to T when conditioned alone (squares) or during extinction of F (circles). Triangles show responding to F during extinction. Solid symbols above Test T- show the individual trials of each test session in Context B while open symbols on the far right show the individual test trials of each session in Context A. See text for further details.

Figure 1

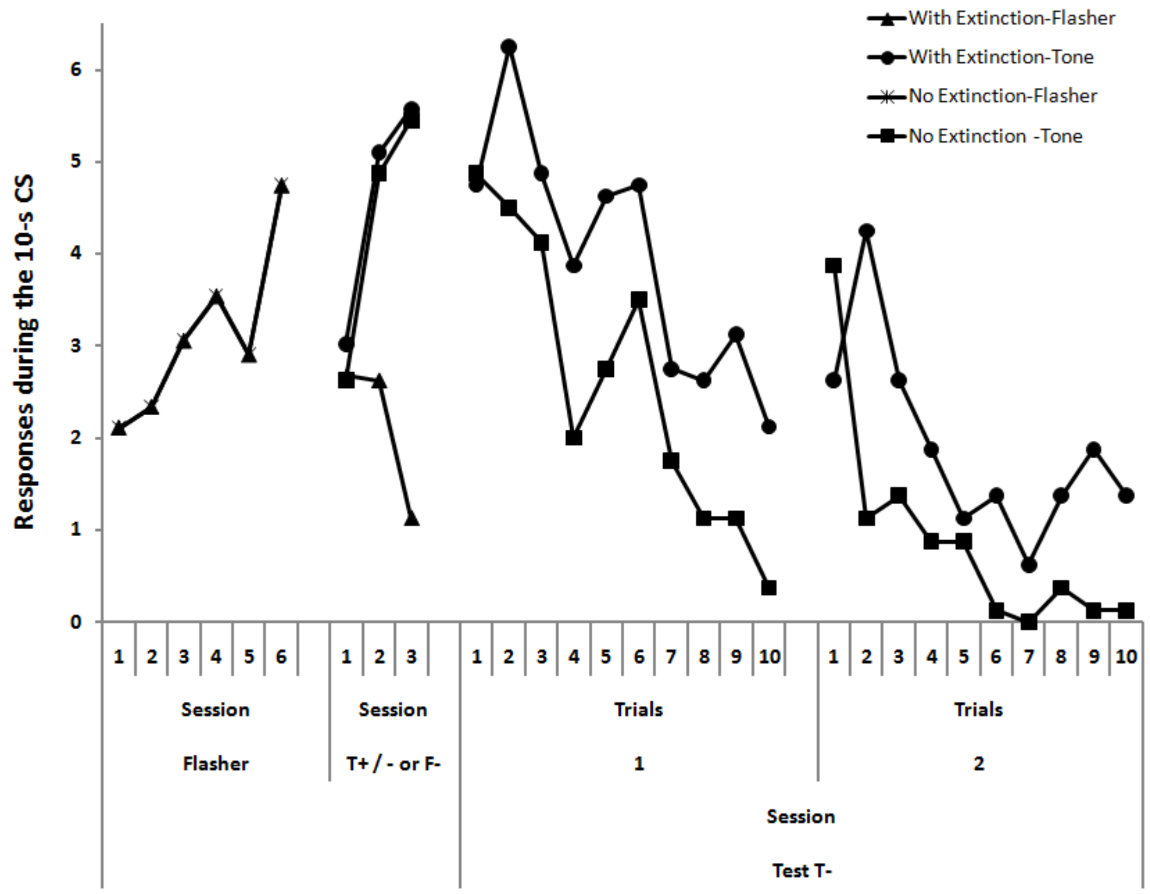
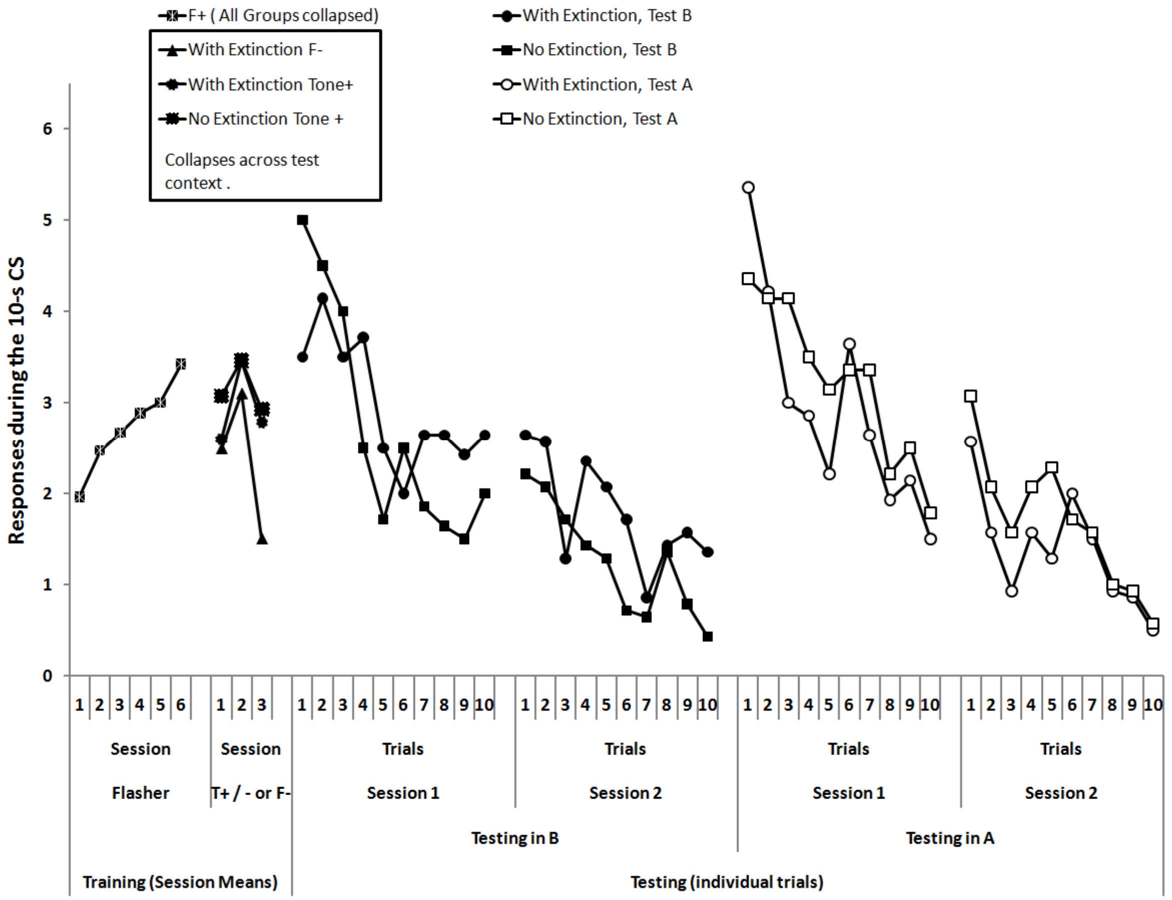

With Extinction-Flasher
With Extinction-Tone
No Extinction-Flasher
No Extinction -Tone
Responses during the 10-s CS
0
1
2
3
4
5
6
1 2 3 4 5 6
1 2 3
1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10
Session
Flasher
Session
T+ / - or F-
Trials
1
Trials
2
Session
Test T-

Figure 2


F+ (All Groups collapsed)
With Extinction F-
With Extinction Tone+
No Extinction Tone +
Collapses across test context .
With Extinction, Test B
No Extinction, Test B
With Extinction, Test A
No Extinction, Test A
Responses during the 10-s CS
0
1
2
3
4
5
6
1 2 3 4 5 6
Session
Flasher
1 2 3
Session
T+ / - or F-
Training (Session Means)
1 2 3 4 5 6 7 8 9 10
Trials
Session 1
1 2 3 4 5 6 7 8 9 10
Trials
Session 2
Testing in B
1 2 3 4 5 6 7 8 9 10
Trials
Session 1
1 2 3 4 5 6 7 8 9 10
Trials
Session 2
Testing in A
Testing (individual trials)