Running Head: EXTINCTION AND ATTENTION

Extinction arouses attention to the context in a behavioral suppression method with humans.

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Abstract

One experiment assessed predictions from the Attentional Theory of Context Processing (ATCP, Rosas, Callejas-Aguilera, Ramos-Álvarez, & Abad, 2006) that extinction arouses attention to contextual stimuli. In a video-game method participants learned a bi-conditional discrimination (RG+/BG-/RY-/BY+) either after extinction of another stimulus had occurred, or not. When contextual stimuli were relevant to solving the discrimination (i.e., all RG+/BG- trials occurred in one context and all RY-, BY+ in another) prior extinction of another stimulus facilitated the discrimination, as if extinction enhanced attention to the contexts. Results are discussed briefly in terms of ATCP and the model of Schmajuk, Lam, & Gray (1996).

Keywords: Extinction, renewal, attention, conditioning, humans

Extinction arouses attention to the context in a behavioral suppression method with humans.

In their "Attentional theory of context processing" (ATCP) Rosas, Callejas-Aguilera, Ramos-Alvarez, and Abad, (2006; see also, Callejas-Aguilera & Rosas, 2010; Rosas & Callejas-Aguilera 2006) extended the idea that attention is aroused to contextual stimuli when signals within that context become ambiguous. Conditioning and extinction with a discrete conditioned stimulus (CS) represents one example of such a situation. Initial CS-Unconditioned stimulus (US) pairings are thought to endow the CS with an excitatory association and the following extinction is thought to then endow the CS with an inhibitory association (e.g., Bouton, 1993; Schmajuk, Lam, and Gray, 1996; Wagner, 1981). Thus, as Bouton describes the situation, the CS can be described as ambiguous in that it can control two conflicting associations.

Under conditions where ambiguity is present, Bouton (1997) suggested that attention is aroused to the context to resolve that ambiguity. That idea was expanded by hypothesizing that another product of such attention is the context-specificity of all subsequently learned information (Rosas & Callejas-Aguilera, 2006). As Nelson, Lombas, and León (2011) discussed, results consistent with that hypothesis are reasonably well established within verbal predictive-learning methods. For example, in a task used by Rosas and Callejas-Aguilera, participants were presented with trials where they read that individuals had consumed particular foods (CSs) in restaurants (contexts) that were followed by particular gastric outcomes (e.g., diarrhea, USs). It has been shown in a variety of such similar tasks that high predictive ratings of cue-outcome relationships are context specific when those particular cue-outcome relationships were learned while different cue-outcome relationships were being extinguished (e.g., Nelson & Callejas-Aguilera, 2007; Rosas & Callejas-Aguilera, 2006).

The theory is important, in part, because it begins to provide an account of the "renewal" effect. Renewal refers to the recovery of an extinguished response that occurs when the extinguished CS is encountered outside the context where extinction occurred. Such recovery occurs when conditioning is conducted in one context (A), extinction occurs in a different context (B) and testing occurs either in the original context A, or another (C). It has also been observed when conditioning and extinction take place in the same context, and testing in a second different context (see Rescorla, 2008, for examples of these ABA, ABC and AAB effects). Nelson, Gregory, and Sanjuan (2012) point out that the effect is not limited to simple conditioning and extinction, but is also evident in counter-conditioning (Peck & Bouton, 1990) where a CS is associated with different USs (e.g., food and shock) across phases. The renewal effect is relevant to behavior therapy (Bouton & Nelson, 1998), emotional intelligence (Nelson & Bouton, 2002), occasion setting (Nelson & Bouton, 1997), and other interference effects found in associative learning (Bouton, 1991). Thus, any theory that can accurately accommodate the effect across the range of conditions where it is observed is one of broad importance.

Though the evidence for the hypothesis proposed by Rosas and Callejas-Aguilera (2006) is mixed with animals (Rosas & Callejas-Aguilera, 2007, obtained the effect while Nelson, Lombas, & Leon, 2011, did not), the evidence with humans from predictive learning tasks is consistently in the hypothesis' favor. One shortcoming in those data, noted by both Rosas and Calljas-Aguilera (2006) and Nelson et al. (2011), is that there is no independent evidence of attention being aroused by extinction outside of the effect which it is invoked to explain. The goal of the present experiment was to obtain evidence of attention being aroused to a context as the result of extinction, independently of the context-specificity effects which it is assumed to produce.

The present experiment sought evidence for attention to the context as the result of extinguishing a CS. According to any theory of learning that incorporates the construct (e.g., Mackintosh, 1975; Pearce & Hall, 1980; Schmajuk, Lam, & Gray, 1996), one effect of attention is to facilitate learning about the attended stimulus. To demonstrate such facilitated learning, we trained participants on a difficult discrimination and made the context relevant to solving that discrimination, or not. Prior to encountering the discrimination, half the participants received conditioning and extinction with a CS (not used in the discrimination), while the other half received conditioning, but no extinction. If extinction enhances attention to a context, then it should facilitate learning the difficult discrimination when the context is relevant, and, at best, have no effect when the context is unrelated to the solution.

Method

Participants

Ninety four college student volunteers (48% male) with a mean age of 19 years (s = 1.1) participated in the experiment. All procedures had been approved by the relevant institutional review boards.

Apparatus

The same apparatus as was used and described in detail by Nelson and Sanjuan (2006; 2008; Nelson, Sanjuan et al., 2011) was used here with the exception that the video game was played on Dell Latitude laptop computers with 14.1inch monitors. 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 computer mouse's left button. 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.

On the laptop screen, a full-screen image was presented as if the participant was sitting inside of a spaceship looking out of a viewscreen. At the bottom of the screen five black ovals were visible, centered, and spaced at intervals of approximately 2 cm which served as the "sensors." Three colored backgrounds were available, provided by Hubble space telescope photos of the Eagle nebula ("Pillars of creation" area) or the Crab nebula (predominately red) 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 one or more of the sensors.

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 a function of clicking the mouse. In general, the greater the participant suppressed mouse clicking during the CS, the less time the controls were frozen, 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.

Context changes were initiated by the appearance of a standard Microsoft Windows Message Box. The text, "Please attend to this important message" was displayed on the title bar of the message box, and the text in the message box read, "You, your sensors, and the enemy are being transported to _____ for further testing. Press OK to proceed." When the participant pressed the "OK" button, another message box was displayed. The text, "Press OK now for immediate transport" was displayed on the title bar, and the text in the message box read, "Remember, you, your sensors, and the enemy are being transported to ______." When the participant pressed the "OK" button, the screen flickered and the current background (e.g., Crab Nebula) was replaced with the alternative (e.g., Eagle Nebula). The blanks were filled with the names of the galaxies; "red galaxy", "blue galaxy", for the Crab and Eagle nebula galaxies, respectively.

Procedure

Conditions were randomly assigned to each participant with each condition having an equal probability of being assigned to a participant. Participants were run individually. Following obtaining informed consent, they were positioned at the computer and handed the instructions which they read to themselves, and then followed along as the attending researcher read the instructions aloud. They were then instructed to place one hand on the mouse and to press the "S" key, beginning the game.

Conditioning and extinction of P. An overview of the design is shown in Table 1. All participants began with eight P+ conditioning trials with a purple sensor (Red 255 + Blue 255) positioned at the second position from the left in Context A ("red galaxy"). The inter-trial interval (ITI), time from US offset to CS onset on reinforced trials, or CS offset to CS onset on non-reinforced trials, averaged 9.5 s (range 7-12 s). Following conditioning, half the participants (With Extinction groups) received eight extinction trials with the purple sensor (P-) in Context A where the sensor appeared for 5 s with no attack. The ITI characteristics in this phase were the same as in the previous phase. The other half of the participants (No Extinction groups) played the game for the same amount of time in Context A with no events occurring during this phase.

Bi-conditional discrimination. Following the extinction phase, all participants received a bi-conditional discrimination using a red sensor (R) in position 3 from the left, a yellow (red 255 + green 255) sensor (Y) in position 4 from the left, a green sensor (G) in position 3 from the left, and a blue sensor (B) in position 4 from the left. Sensors were presented in pairs. RG and BY were followed by an attack US (+). BG and RY were not followed by an attack (-). Thus, the discrimination was of the form RG+/BG-/BY+/RY-. All participants received 96 trials, 24 of each type, with an average ITI of 9.47 s (range 7-12 s). Both the With Extinction and No Extinction groups were subdivided into Context Relevant, Trials Same, and Contexts Same conditions.

To demonstrate how the trials were arranged during the Bi-Conditional discrimination, refer to Table 1 and consider the trials as occurring in six blocks of 16. Table 1 shows a representative 16-trial block. Each 16-trial block in the Context Relevant condition consisted of two blocks of four trials with RG+ and BG- shown under the label "---Context A---" followed by two blocks of four trials with RY- and BY+ shown under "===Context B===." The first block of trials in Context A is shown in normal font, the second is underlined. The first block of trials in Context B is in italics, while the second is in normal font. These trials are marked in the table to facilitate demonstrating how they will be interchanged later. The trial sequence within each of these four-trial blocks was randomly determined.

The Trials Same condition was formed by maintaining the same trial sequences across the 96 trials as the Context Relevant condition, but the contexts were alternated every 16 trials. Every trial type was experienced in each context and the contexts were therefore uncorrelated with the types of trials that occurred in each.

The Contexts Same condition was formed by maintaining the same sequence of context changes, changing every eight trials, as in the Contexts Relevant condition while mixing the trial types within each context. Within each 16-trial block, the same sequence encountered in the Context Relevant condition during the second four-trial block in Context A (the underlined trial types) was interchanged for the *first* four-trial block that occurred in Context B (italicized).

We did no counterbalancing within the With Extinction and No Extinction conditions in this experiment. The stimulus pairs were not counterbalanced with respect to their outcomes, nor were the positions of the reinforced and non-reinforced trials in the sequence counterbalanced. Context "A" was always the context containing a predominately red background, while context "B" was always the context containing the predominately blue background. Our reasons for that were simple. Such counterbalancing was not necessary for our hypothesis. We had six main experimental conditions, and the substantial increase in the number of experimental conditions required by the counterbalancing would unnecessarily increase the probability of losing valuable participants through experimenter error. The lack of counterbalancing would only affect any conclusions we might draw as to *why* the within-subject discriminations might be formed. That is, we cannot say that any differences in suppression observed between reinforced and non-reinforced trials were due to the outcomes as those were confounded with the identity of the stimulus pairs, their position in the trial sequence, and the physical characteristics of the contexts in which they occurred within each group. However, the actual cause of the discrimination is not important. What is important is the relationship of the contexts to the discrimination that was manipulated between groups, regardless of why the discrimination was formed.

Data Analysis

The computer recorded the number of mouse click responses during the presentation of the sensor CSs and during the preceding 5 seconds (pre-CS). These data were converted to standard suppression ratios [CS / (pre-CS + CS)] for analysis with Analysis of Variance (ANOVA). Simple effects were conducted with ANOVA using error terms derived by pooling the relevant terms from the overall mixed-factorial analyses (Howell, 1987) with the degrees of freedom reduced using the Welch (1938) and Satterthwaite (1946) procedures to compensate for the pooling of potentially heterogeneous variances. Probabilities less than .05 were considered significant. Both exact probabilities and effect sizes are reported for the reader. For analyses involving more than two means effect sizes are reported as partial eta-squared (η^2_p). Cohen's *d* was computed for analyses involving only two means. To best represent the size of the effect given the directly observable variability, *d* was computed using the pooled variance around the two means being compared regardless of whether the comparison was between- or within-subjects.

Consistent with Nelson, Sanjuan et al., (2011) we excluded participants who failed to learn in the initial conditioning phase. Only the initial conditioning phase was used to screen participants as subsequent responding could be related to the experimental manipulations. Participants for whom suppression on 2 out of the last 3 trials was not lower than the first trial were excluded. We also excluded participants with low average rates of baseline responding (pre-CS counts less than 5) across the experiment as such low rates make for a coarse measure of suppression and that criterion was successful in eliminating participants who had occasional pre-CS rates of zero, for which calculation of suppression would be impossible.

Results

Assignment and exclusion.

Random assignment placed 15 subjects in each of the With Extinction groups. Among the No Extinction groups there were16 in the Context Relevant and Trials Same conditions with 17 in the Contexts Same condition. Application of the exclusion criteria eliminated five subjects: One from the With Extinction, Contexts Same condition, one from the No Extinction, Trials Same condition, and three from the No Extinction, Contexts Same condition. Exclusion was independent of group, χ^2 (5) = 7.80, *p* = .17.

Conditioning and extinction of P.

All conditions acquired suppression to P equally over the eight conditioning trials. Suppression averaged .53 on Trial 1 and .12 on Trial 8. An Extinction x Context Relation x Trials ANOVA revealed an effect of Trials, $F(7,83) = 120.33$, $p < .001$, $\eta^2_p = .59$, and no other effects, Fs < 1.

Suppression was reduced equally over eight trials in the two conditions receiving extinction. Suppression averaged .1 on Trial 1 of extinction and .28 on Trial 8. A Context Relation x Trials ANOVA revealed an effect of Trials, $F(7,41) = 14.07$, $p < .001$, $\eta^2_p = .26$, and no other effects, $F\text{s} \leq 1.55$, $p\text{s} \geq .23$.

Bi-conditional discrimination training.

The data from the bi-conditional discrimination are shown in Figure 1. The points collapse across the stimulus pairs that received the same outcomes so that RG+ and BY+ combined are represented by "+ trials", and RY- and BG- combined are represented by "- trials". All groups learned the discrimination, though the discrimination was learned most rapidly in the Context Relevant conditions. Extinction also affected the discrimination. Extinction enhanced learning the discrimination when the contexts were relevant, and somewhat hindered learning the discrimination when the contexts were irrelevant.

These data were analyzed by an Outcome (reinforced vs. non-reinforced) x Extinction x Context Relation x Trials ANOVA. There were Outcome x Trials x Extinction and Outcome x Trials x Context Relation interactions, $F\text{s}(23,1909) \geq 1.77$, $p\text{s} \leq .02$, $\eta^2_p \geq .02$. There was an Extinction x Context Relation interaction, $F(2,83) = 5.27$, $p = .007$, $\eta^2_p = .11$. Of most importance, there was an overall Outcome x Extinction x Context Relation interaction, $F(2,83) = 3.98$, $p = .02$, $\eta^2_p = .09$. No other effects, not already superseded by an interaction, were reliable, $F\text{s} \leq 2.25$, $p\text{s} \geq .06$.

The Outcome x Extinction x Context Relation interaction was further analyzed by collapsing across the trials. Those data are shown in Figure 2. Darker bars (black and heavy gray) represent the With Extinction conditions. Lighter bars (white and light gray) are from the No Extinction conditions. Reinforced trials are shown over "+Trials" and non-reinforced trials are shown over "- Trials." The dark and light gray bars above "+/- Discrimination" represent the size of the discrimination (i.e., the Outcome effect) obtained by subtracting the reinforced from the non-reinforced trials.

All groups acquired the discrimination. The difference between the "+ Trials" and "- Trials" was reliable in all groups, $F\text{s}(1,83) \geq 38.03$, $p\text{s} \leq .001$, $d\text{s} \geq 2.47$.

Considering the effects of extinction (black vs. white bars) on "+ Trials", there were no detectable effects of extinction in any group, $F\text{s} \leq 3.14$, $p\text{s} \geq .08$. On "- Trials", extinction had an impact in the Context Relevant condition, lowering suppression, $F(1,166) = 4.59$, $p = .03$, $d = 1.22$. There was no detectable effect in the Trials Same condition, $F = 1.58$, $p = .21$, and extinction had the opposite effect in the Contexts Same condition, $F(1,166) = 8.61$, $p = .004$, $d = 0.9$, where suppression increased.

Within the With Extinction condition (black bars), there were no differences between the groups on the reinforced trials, *F*s < 1. On the non-reinforced trials the Context Relevant condition showed less suppression than the other two conditions, which also differed from each other, *F*s(1,166) ≥ 10.83, *p*s ≤ .001, *d*s ≥ .99.

Within the No Extinction conditions (white bars), on "+ Trials" the Trials Same group showed less suppression than the Contexts Same condition, *F*(1,166) = 4.61, *p* = .03, *d* = 1.26, with no other differences among the groups, *F*s ≤ 1. On "- Trials" trials, there were no differences among the conditions, *F*s ≤ 2.50, *p*s ≥ .12.

Looking at the discrimination itself, the difference between "+ Trials" and "- Trials" represented by the gray bars, extinction increased the discrimination relative to no extinction in the Context Relevant condition, *F*(1,83) = 9.15, *p* = .003, *d* = 1.34. Extinction reduced the size of the discrimination in the Trials Same condition, *F*(1,83) = 5.53, *p* = .02, d = .69. Extinction had no detectable effect in the Contexts Same condition, *F*(1,83) = 1.28. Within the extinction condition (dark gray bars), the discrimination in the Context Relevant condition was larger than the other two conditions, who also differed from each other, *F*s(1,83) ≥ 5.47, *p*s ≤ .02, *d*s ≥ .5, Within the no-extinction condition (light gray bars), there was no difference between the Context Relevant and Trials Same condition, *F*(1,83) = 1.19, *p* = .28, but both of those differed from the Contexts Same condition, *F*s(1,83) ≥ 6.14, *p*s ≤ .02, *d*s ≥ .57.

Discussion

The experiment was designed to determine if extinction would lead to an enhancement of attention to contextual cues as assessed by the rate of learning that occurs within these contexts. Participants were trained in a bi-conditional discrimination where the context was relevant to solving the discrimination or not. Prior to the discrimination participants received conditioning with another CS that was not part of the bi-conditional discrimination. Half of those participants then received extinction with that CS which, according to ATCP (Rosas, Callejas-Aguilera et al., 2006), should enhance attention to contextual stimuli. That enhanced attention to contexts should facilitate solving the discrimination when the contexts were relevant to the solution.

The findings were clear. Participants learned the discrimination most rapidly when the context was relevant to the solution, and extinction prior to the discrimination did enhance that discrimination. Participants that received the same order of trials, with context-changes unrelated to the identity of the stimuli within those trials, learned the discrimination less rapidly, and extinction hindered the discrimination. In that group, Trials Same, the contexts were unrelated to the sequence of trials within them, and attention to the context might have led to a disruption in either responding or non-responding (see Nelson & Sanjuan, 2008) making the discrimination appear more slowly. It is worth noting that the effect of context change was predominately on the non-reinforced trials, which suggests that excitation was acquired first, and second-learned inhibition was more contextually controlled (e.g., Nelson, 2002). ATCP presently makes no allowance for differential levels of contextual control between first and second-learned information. In the final condition, the sequence of context changes remained the same as in the Context Relevant condition, but the trial sequence was jumbled so that the context changes were unrelated to the trials within them. In this condition, where the changes in contexts and trial types were the most intermixed, the discrimination was most difficult, and extinction had no clear effect on the discrimination. If anything, extinction appeared to generally increase suppression in that condition.

The attentional model of Schmajuk, Lam, and Gray (1996) would also predict that there would be more contextual attention in the With Extinction groups than in the No Extinction groups. That differential attention would not result from attention being aroused or increased in the With Extinction condition, but from attention simply decreasing less in that condition during the Extinction phase. In the SLG model, attention generally follows a Pearce-Hall (1980) type rule where it decreases to the extent that events are predicted, and unpredicted events lead to novelty which increases or restores attention. In the No Extinction groups, exposure to the context alone would lead to a decrease in attention, while the absence of the US and the presence of P would, to a certain degree, be novel events, maintaining attention to the contexts in the With Extinction conditions. For the discriminations ultimately to be solved, the model would have to incorporate configural units. Though such units have been suggested by Larrauri and Schmajuk (2008), we are aware of no full and formal description of their use and the conditions under which they would be formed. It remains to be specified whether, or when, configural units should be the result of CS pairs, CS and Context groupings and so forth. As such, exact predictions from the model on the effects of that differential attention are unavailable.

Although general predictions regarding the heuristic that ambiguity produced by extinction increases attention to contexts can be made with ACTP, more formal predictions are not possible with its current level of specification. Moreover, it does not yet specify what the results of the increased attention will be in mechanistic terms. Such attention might foster the context to enter into direct associations with the US, or hierarchical associations as described by Bouton (1993), or both. Nevertheless, the effects demonstrated here were consistent with the general principle offered by ATCP. Extinction of a CS affected subsequent processing of events in a way indicative that attention to contextual stimuli was enhanced.

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Table 1

Design of Experiment

<table>
<tr><th>Conditioning of P</th><th>Extinction of P</th><th>Bi-conditional Discrimination</th></tr>
<tr><td rowspan="3">A: P+</td><td>With Extinction
A: P-</td><td>Context Relevant
------------------Context A:------------------ ============Context B:==========
RG+ BG- BG- RG+ | RG+ BG- RG+ BG- | *RY- RY- BY+ BY+* | RY- BY+ BY+ RY-</td></tr>
<tr><td rowspan="2">No Extinction
A: --</td><td>Trials Same
(Contexts A and B alternate every 16 trials)
-=-=-=-=-=-Context A:&B:=-=-=-=-=-= -=-=-=-=-=-Context A:&B:=-=-=-=-=-=
RG+ BG- BG- RG+ | RG+ BG- RG+ BG- | *RY- RY- BY+ BY+* | RY- BY+ BY+ RY-</td></tr>
<tr><td>Contexts Same
------------------Context A:----------------- ============Context B:===========
RG+ BG- BG- RG+ | *RY- RY- BY+ BY+* | RG+ BG- RG+ BG- | RY- BY+ BY+ RY-</td></tr>
</table>

Note: Each of the With Extinction and No Extinction groups designated in Phase 2 were subdivided into the three groups shown under Bi-conditional Discrimination. Context A: and Context B: are different space-background contexts in a video-game method. P is a purple sensor CS. R, G, B, and Y refer to red, green, blue, and yellow sensor CSs, respectively. "+" indicates an attack US, "-" indicates no event. "|" separates blocks of trials. " ----Context A:----" indicates trials occurring in Context A:, "====Context B:====" indicates trials occurring in Context B:, "-=-=-=Context A:&B:-=-=-=" indicates trials occurring in both contexts. Italicized and underlined trial types are marked to illustrate how the trial orders changed between conditions. See method for further details.

Figure Captions

Figure 1. Suppression ratio (Y axis) data from the bi-conditional discrimination phase in Experiment 1. X axis shows groups and trials. Solid symbols show the groups that received extinction of P prior to the discrimination. Open symbols show the groups that did not receive extinction prior to the discrimination. Circles show responding on reinforced trials, squares show responding on non-reinforced trials.

Figure 2. Suppression ratio (Y axis) data from the bi-conditional discrimination phase in Experiment 1, collapsed across the trials shown in Figure 1. Dark bars (black and dark gray) show responding in the groups that received extinction of P prior to the discrimination. Lighter bars (white and light gray) did not receive extinction prior to the discrimination. X axis shows groups and trial types. Bars on the columns represent the standard error of the mean.

Figure 1

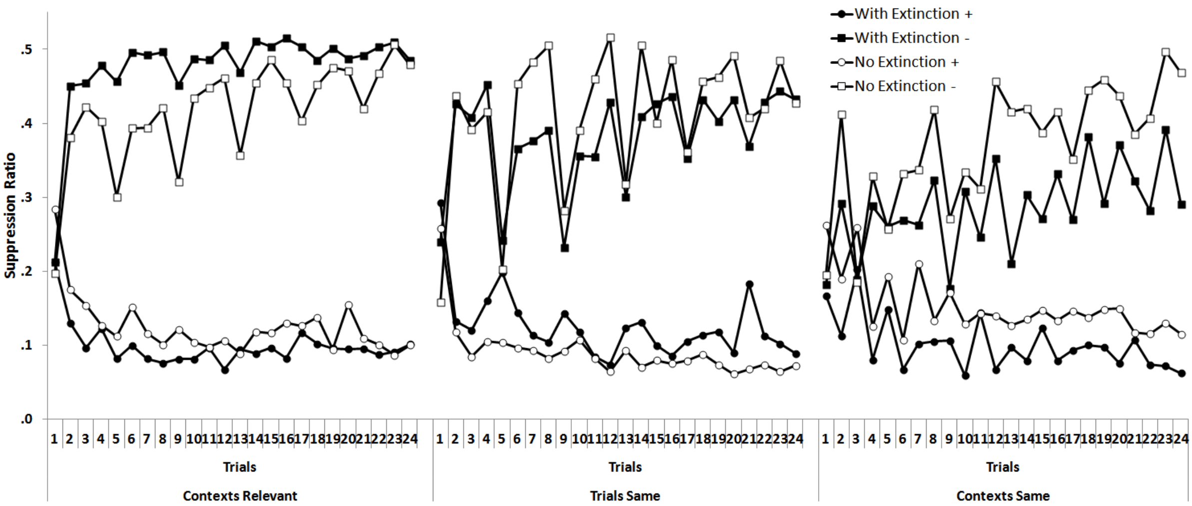
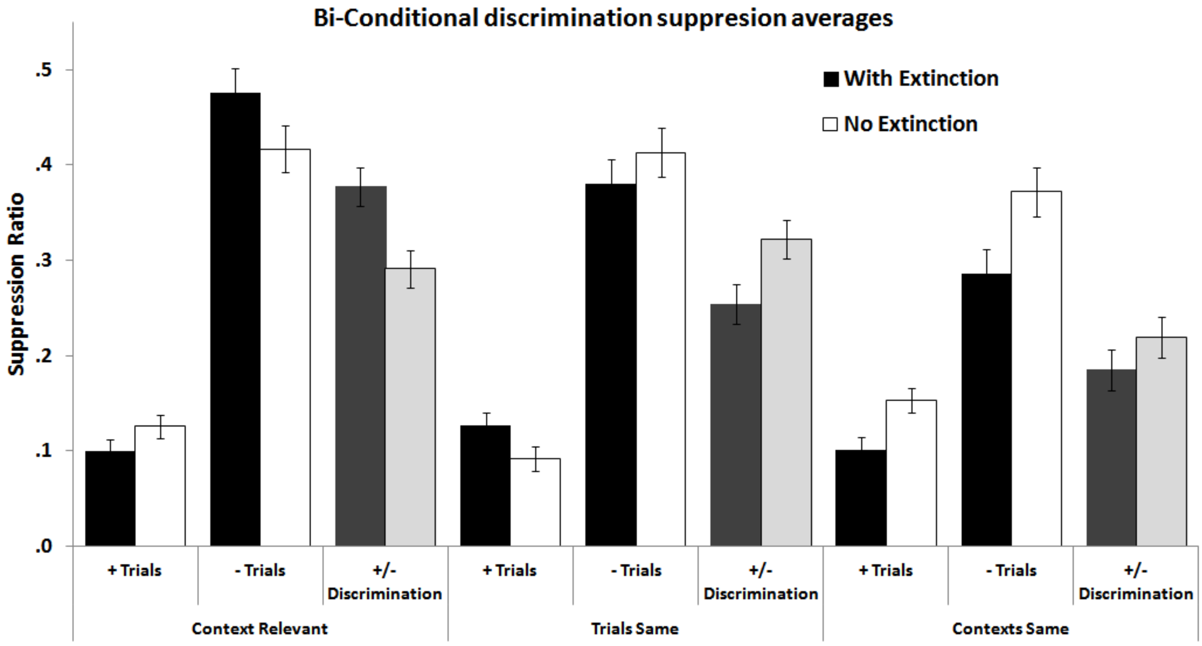

With Extinction +
With Extinction -
No Extinction +
No Extinction -
Suppression Ratio
.0
.1
.2
.3
.4
.5
Trials
Contexts Relevant
Trials
Trials Same
Trials
Contexts Same

Figure 2


Bi-Conditional discrimination suppresion averages
With Extinction
No Extinction
Suppression Ratio
.5
.4
.3
.2
.1
.0
+ Trials
- Trials
+/- Discrimination
+ Trials
- Trials
+/- Discrimination
+ Trials
- Trials
+/- Discrimination
Context Relevant
Trials Same
Contexts Same