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Contrasting the Overexpectation and Extinction Effects

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Abstract

After many target stimulus (X)-unconditioned stimulus (US) pairings, further conditioning of X in the presence of another well-established signal for the US (A) disrupts X's behavioral control. Some researchers have argued that the mechanism underlying this so-called overexpectation effect is similar to that underlying extinction (a reduction in X's behavioral control due to X-alone presentations). Three conditioned suppression experiments with rats as subjects compared overexpectation and extinction. Experiment 1 replicated the basic overexpectation effect by showing that A disrupts responding to X more than does a previously neutral stimulus. Experiment 2 found that posttraining context exposure disrupts extinction but not overexpectation. Experiment 3 suggested that overexpectation and extinction are differentially sensitive to the effects of overtraining (compound reinforced or nonreinforced, respectively), such that extinction is enhanced by increases in the amount of nonreinforced trials and overexpectation is unaffected. These results are inconsistent with the view that overexpectation and extinction are driven by a common mechanism.

Keywords

cue competition; overexpectation; extinction; Pavlovian conditioning

1. Introduction

The overexpectation effect (e.g., Rescorla, 2006) refers to a decrease in the response potential of an asymptotic excitatory target CS (X) as a result of pairing X with the unconditioned stimulus (US) in the presence of a second asymptotic signal for the US (A). At least superficially, the overexpectation effect is similar to the extinction effect, which refers to the response decrement to X often observed when X is nonreinforced after asymptotic conditioning. In both cases, the US expected based on the cues present is greater than the US delivered.

Several similarities between overexpectation and extinction prompted Rescorla (2006, 2007) to conclude that overexpectation and extinction are driven by the same underlying mechanism. First, both effects involve reduced responding to a previously asymptotic CS. Second, in an effort to test the view that overexpectation and extinction are driven by similar mechanisms, Rescorla (2006) observed that a similar phenomenon (spontaneous recovery) occurs when a retention interval is administered between AX-US (overexpectation) trials and testing. Third, the expression of both effects can be controlled by the context in which testing occurs.

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Responding to X following extinction increases (i.e., is renewed) when testing occurs outside the extinction context (Bouton and Bolles, 1979). The strongest type of renewal occurs when the context of extinction treatment (Context B) is different from that of acquisition and testing (Context A). In ABA renewal, X's behavioral control is greater than if testing occurs in the context of extinction (i.e., an ABB condition). Similarly, renewal after overexpectation has been observed when elemental conditioning (A-US/X-US) and testing occurred in Context A and overexpectation treatment (AX-US) occurred in Context B (Rescorla, 2007). Thus, renewal can be observed after both overexpectation and extinction. Fourth, increasing the interval between response-reducing (overexpectation or extinction) trials makes these trials more effective in attenuating responding. Data from our laboratory indicate that the interval between nonreinforced trials is directly related to the effectiveness of extinction, such that long intervals support enhanced extinction (Urcelay, Wheeler, and Miller, in press). Moreover, the overexpectation effect appears to be weaker with short relative to long intervals between compound trials (Sissons and Miller, 2008).

Some of these similarities prompted Rescorla (2006; 2007) to argue that overexpectation and extinction are supported by similar mechanisms. However, to our knowledge, no direct comparison of these effects has been conducted. Claims of similarities between overexpectation and extinction are based on between-experiment comparisons; thus, differences between these effects might have eluded previous researchers because no explicit efforts to compare the effects have been made. The purpose of the present experiments was to contrast overexpectation and extinction with respect to the effect of context postexposure (Experiment 2) and increasing the number of response-decreasing trials (Experiment 3).

2. Experiment 1

The purpose of Experiment 1 was to replicate the basic overexpectation effect relative to a conservative control group. The parameters of the present experiment were modelled after two recent replications of the overexpectation effect in our laboratory (Blaisdell, Denniston, and Miller, 2001; Sissons and Miller, 2008). For two reasons, the present experiment compared an overexpectation group to a control group in which subjects were exposed to a compound consisting of the target and a neutral stimulus during Phase 2. First, in Blaisdell et al.'s (2001) experiment, this control group exhibited the weakest behavioral control and was thus the most conservative control group. Second, we sought to separate the overexpectation effect from the response decrement that can occur when an excitatory target stimulus is reinforced in compound with a neutral stimulus (e.g., Arcediano, Escobar, and Miller, 2004), thereby demonstrating the necessity of Phase 1 reinforcement of the target's companion stimulus. Thus, two groups were included in Experiment 1: Groups Overexpectation (AX+) and Control (BX +; see Table 1).

2.1. Materials and Methods

2.1.1. Subjects—Subjects were 12 female and 12 male Sprague-Dawley, experimentally naïve, young adult rats. Body weights for females were 179–232 g and for males were 276–331 g. Subjects were individually housed and maintained on a 16-hr light/8-hr dark cycle with experimental sessions occurring roughly midway through the light portion. Subjects had free access to food in the home cage. Prior to initiation of the experiment, water availability was progressively reduced to 20-min per day, provided soon after scheduled treatments.

2.1.2. Apparatus—Two different types of enclosures (counterbalanced within groups) served as Context Train. Enclosure R was a clear, Plexiglas chamber in the shape of a rectangular box 22.75 × 8.25 × 13.0 cm (l × w × h) with a floor constructed of 0.48 cm diameter stainless steel rods 1.5 cm apart, center-to-center, connected by NE-2 neons. The grid floor allowed a 0.3-s, 0.7-mA constant-current footshock to be delivered by means of a high voltage

AC circuit in series with a 1.0-MΩ resistor. Each of six copies of Enclosure R had its own environmental isolation chest and was dimly illuminated by a 2-W (nominal at 120 VAC) bulb driven at 80 VAC and mounted on an inside wall of the environmental isolation chest approximately 30 cm from the center of the animal enclosure.

Enclosure V was a 25.5-cm long box in the shape of a truncated-V (28 cm high, 21 cm wide at the top, 5.25 cm wide at the bottom). The floor and long sides were constructed of stainless steel sheets. The ceiling was clear Plexiglas and the short sides were black Plexiglas. The floor consisted of two parallel metal plates each 2-cm wide with a 1.25-cm gap between them, which could deliver a 0.7-mA, 0.3-s constant-current footshock. Each of six copies of Enclosure V had its own environmental isolation chest, which was dimly illuminated by a 7-W (nominal at 120 VAC) bulb driven at 80 VAC mounted on an inside wall of the environmental isolation chest approximately 30 cm from the center of the animal enclosure, with the light entering the animal enclosure primarily reflected from the roof of the environmental chest. Due to differences in opaqueness of the enclosures, this level of illumination roughly matched that of Enclosure R.

A third chamber served as Context Test for all subjects. Twelve identical chambers, each measuring 30 × 25 × 32 cm (l × w × h), were used. The walls of each chamber were made of clear Plexiglas, and the floor was constructed of 0.5 cm diameter rods, spaced 2 cm center-to-center. Each chamber was housed in an environmental isolation chest, which was dimly illuminated by a houselight (#1820) mounted on the ceiling of the experimental chamber. On one metal wall of each chamber, there was an operant lever and adjacent to it a niche (4.5 × 4.0 × 4.5 cm) centered 3.3 cm above the floor through the top of which a solenoid-driven valve could deliver 0.04 ml of water into a cup. A 0.5-s SonAlert presentation signalled water delivery to facilitate magazine approach.

Each chamber was equipped with three speakers on the inside walls of the environmental chest. Each speaker could deliver a different auditory stimulus, each 8 dB (C-scale) above background: a click train (6 Hz), a white noise, and a complex tone composed of two high frequencies, 3000 and 3200 Hz, presented simultaneously. Ventilation fans in each chest provided a constant 74-dB(C) background noise. The tone and white noise served as stimuli A and B, counterbalanced within groups and the clicks served as the target stimulus (X).

2.1.3. Procedure—Subjects were randomly assigned to one of two groups: BX+ and AX+ (*n*s = 12). Subjects were shaped to lever press for water reinforcement and tested in Context Test, and were exposed to target training in a physically distinct context (Context Train). Changing contexts served to minimize summation of the behavioral control of the test context with that of the target CS.

2.1.3.1. Shaping and Acclimation: Prior to conditioning, a 5-day acclimation and shaping regimen established stable rates of lever pressing in Context Test for water reinforcement on a VI 20-s schedule. The VI 20-s schedule of reinforcement prevailed throughout reshaping and testing.

2.1.3.2. Phase 1: On Days 6 through 8 in Context Train, all subjects were exposed to Phase 1 training consisting of 4 CS-US parings per daily 60-min session. A-US trials occurred at 6 and 34 minutes into each session. X-US trials occurred at 18 and 49 minutes into each session.

2.1.3.3. Phase 2: On Days 9 through 12 in Context Train, all subjects were exposed to 2 daily trials at 6 and 20 min into each 30-min session. Subjects in the AX+ condition were exposed to AX-US trials and subjects in Group BX+ were exposed to BX-US trials.

2.1.3.4. Reshaping: On Days 13 through 15, baseline recovery training on the VI-20-s schedule was conducted in Context Test to stabilize baseline behavior that might have been disrupted by the US. During this period, all subjects received daily 1-hr sessions.

2.1.3.5. Testing: On Day 16, suppression of responding during presentation of CS X was assessed in Context Test. Each subject received three 30-s presentations of X during a 30-min session initiated at 8, 13, and 18 min into the session. Lever pressing during the 60-s periods preceding each CS exposure (pre-CS score) and that during the 30-s CS exposure (CS score) were recorded.

2.1.3.6. Data analysis: A suppression ratio for each subject was calculated by the formula P/(P + 0.5 * Q), where P is the number of lever presses during the three 30-s CS presentations and Q (Pre-CS) is the number of lever presses during the 60 s immediately preceding each of the three CS test presentations. Thus, a suppression ratio of 0.5 indicates no conditioned suppression and that of 0.0 indicates complete suppression. An alpha of .05 (two-tailed) was set as a reliable difference and an alpha of .10 (two-tailed) was set as marginal. The use of two-tailed tests was conservative given we had clear predictions at the initiation of this research.

2.2. Results and Discussion

Experimenter error caused two subjects from Group AX+ and three subjects from Group BX+ to be eliminated. Group means for suppression in the presence of X are reported in Figure 1. Critically, suppression in the presence of X was greater in Group BX+ than in Group AX+, $t(17) = 2.40$, indicating that X+ trials in the presence of a well-established signal for the US decreased behavioral control by X more than did X+ trials in the presence of a previously neutral stimulus. A *t*-test on the pre-CS scores failed to detect a difference between groups with respect to baseline lever pressing, $t(17) = 1.13$. Thus, Experiment 1 successfully replicated the overexpectation effect.

3. Experiment 2

The purpose of Experiment 2 was to compare the effect of posttreatment context exposure on overexpectation and extinction. Miller and his colleagues have shown that the response degrading effect of extinction can be reduced by context postexposure (Laborda, Witnauer, and Miller, 2008). In contrast, context postexposure often fails to affect response deficits caused by compound conditioning in first-order conditioning (e.g., overshadowing; Sissons, Urcelay, and Miller, 2008). Thus, we anticipated that extinction (a CS-alone treatment) would be disrupted by context postexposure, whereas overexpectation would be unaffected by context postexposure. A 2 (Phase 2 training [AX+ vs. X−]) × 2 (Amount of Context Postexposure [480 min vs. 20 min]) factorial design was used to test this hypothesis (see Table 2).

3.1. Materials and Methods

3.1.1. Subjects—Subjects consisted of 24 male (body weight range was 289–351 g) and 24 female (body weight range was 186–243 g) Sprague-Dawley, experimentally naïve rats. Subjects were bred and maintained as in Experiment 1.

3.1.2. Apparatus—The apparatus used in Experiment 2 was the same as that of Experiment 1.

3.1.3. Procedure—Subjects were randomly assigned to one of four groups (AX+20, AX+480, X-20, X-480; *n*s = 12). Shaping, reshaping, and testing were conducted in Context Test and training was conducted in Context Train. Other than those changes specified below, the procedure of Experiment 2 was the same as that of Experiment 1.

3.1.3.1. Phase 2: On Days 9 through 12 in Context Train, all subjects were exposed to 2 daily trials at 6 and 20 min into each 30-min session. Subjects in the AX+ condition received AX-US trials. Subjects in the X− condition received X-alone trials.

3.1.3.2. Phase 3: On Days 13 through 16 in Context Train, all subjects were exposed to the training context for an amount of time dependent upon group assignment. Subjects in Condition 480 were exposed to the training context for 120 min per daily session, during which experimental chambers were opened every 30 min to assure that subjects were not sleeping. Subjects in Condition 20 were exposed to the training context for 5 min per daily session, which controlled for the handling that subjects received in Condition 480. No nominal stimuli were presented.

3.2. Results and Discussion

Group means for suppression in the presence of X are depicted in Figure 2. The effect of context postexposure depended on whether subjects were exposed to X− or AX+ trials in Phase 2. Within Condition X−, responding to X was greater after 480 min of context postexposure than after 20 min of context postexposure. Within Condition AX+, the opposite pattern of results was observed; responding was greater after 20 min of context postexposure than after 480 min of context postexposure. These impressions were supported by the following analysis.

A 2 (Phase 2 training [AX+ vs. X−]) × 2 (context exposure [20 min vs. 480 min]) ANOVA on lever pressing during the pre-CS intervals failed to detect a main effect or interaction, *p*s > .15, indicating that groups were not differentially afraid of Context Test. A similar ANOVA on suppression during X failed to detect a reliable main effect of either Phase 2 training, $F(1, 44) = 2.80$, or context exposure, $F(1, 44) = 0.89$. Critically, this analysis detected an interaction, $F(1, 44) = 4.18$, suggesting that context postexposure differentially affected suppression in the AX+ and X− conditions. Planned comparisons were conducted to determine the source of the interaction. A difference between Groups X-20 and X-480 was detected, $F(1, 44) = 4.47$, indicating that context postexposure increased suppression in Condition X−. The difference between Groups AX+20 and AX+480 failed to reach significance, $F(1, 44) = 0.60$.

The results of Experiment 2 supported the hypothesis that overexpectation and extinction would be differentially affected by context postexposure. Within Condition X−, the increase in X's behavioral control was consistent with previous research on the relationship between the associative status of the training context and the effect of CS-alone presentations (e.g., Laborda et al., 2008) and the failure to detect a difference within the AX+ condition is consistent with previous research (Sissons et al., 2008). The observation that overexpectation and extinction were differentially affected by context postexposure contrasts with the view that overexpectation and extinction are driven by similar mechanisms (e.g., Rescorla, 2006).

4. Experiment 3

The purpose of Experiment 3 was to further contrast overexpectation and extinction using a manipulation that was expected to enhance extinction and disrupt overexpectation (unlike Experiment 2 where extinction was disrupted). Between-experiment comparisons suggest that extinction and overexpectation might change differentially as a function of the number of response degrading trials. Some data suggest that administering massive numbers of compound conditioning trials can disrupt competition among elements in a compound (e.g., Stout, Arcediano, Escobar, and Miller, 2003). One might expect subjects to recover from the overexpectation effect with similar increases in the number of compound conditioning trials. In contrast, existing data suggest that extinction is enhanced as a result of large numbers of trials (Denniston, Chang, and Miller, 2003). A 2 (AX+ vs. X−) x 2 (Phase 2 trials: 8 vs. 40) factorial design was used to investigate whether the number of response degrading trials differentially affects extinction and overexpectation (see Table 3).

4.1. Materials and Methods

4.1.1. Subjects—Subjects consisted of 24 male (body weight range was 301–414 g) and 24 female (body weight range was 201–268 g) Sprague-Dawley, experimentally naïve rats. Subjects were bred and maintained as in Experiments 1 and 2.

4.1.2. Apparatus—The apparatus used in Experiment 3 was that same as that used in Experiments 1 and 2.

4.1.3. Procedure—Subjects were randomly assigned to the four groups (*n*s = 12) created by this design (Groups 8-AX+, 40-AX+, 8-X, and 40-X). Shaping, Phase 1, Reshaping, Testing, and Data Analysis were conducted in exactly the same way as in Experiment 2.

4.1.3.1. Phase 2: On Days 9 through 12 in Context Train, subjects in Condition 8 were exposed to 2 trials at 6 and 20 min into each daily 30-min session as in Experiment 2. Subjects in the 40 condition were exposed to 10 trials at 6, 20, 36, 54, 67, 78, 96, 115, 130, and 143 min into each daily 150-min session. Subjects in the AX+ condition were exposed to training consisting of AX-US trials (the amount of which was dependent upon group assignment) and subjects in the X− condition were exposed to an equivalent number of X-alone presentations.

4.2. Results and Discussion

Figure 3 illustrates mean suppression at test in the presence of X. The effect of increasing the number of Phase 2 trials from 8 to 40 depended on the type of Phase 2 trial administered. Within Condition X−, suppression was attenuated after 40 X− trials relative to 8 trials. In contrast, within Condition AX+ suppression was greater after 40 than after 8 AX+ trials. Inferential statistics lent some support for these observations.

A 2 (Phase 2 training [AX+ vs. X−]) × 2 (Phase 2 trials [8 vs. 40]) ANOVA on the number of pre-CS lever presses failed to detect any main effects or interaction, *p*s > .43. A similar ANOVA on the suppression ratios failed to detect an effect of Phase 2 trial amount, $F(1, 44) = 0.36$, but detected a main effect of Phase 2 training, $F(1, 44) = 4.95$. Critically, a marginal interaction between Phase 2 training and Phase 2 trial amount, $F(1, 44) = 3.68$, $p < .07$, indicated that suppression to X in the X− and AX+ conditions was differentially affected by the number of Phase 2 trials. Planned comparisons were conducted to determine the source of this interaction and to test specific hypotheses. A marginal difference between Group 8-X and Group 40-X, $F(1, 44) = 3.17$, $p < .09$, indicates that suppression to X decreased as a result of increasing the number of X− presentations from 8 to 40. In contrast, a statistically nonsignificant tendency towards more suppression in Group 40-AX+ relative to 8-AX+ was observed, $F(1, 44) = 0.87$.

The results of Experiment 3 provide limited support for the hypothesis that extinction and overexpectation are differentially affected by increasing the number of response degrading trials. Extinction was enhanced by increasing the number of trials, which is consistent with prior research (Denniston et al., 2003). The hypothesis concerning trial dynamics in overexpectation was not supported. Specifically, based on previous investigations (e.g., Stout et al., 2003), the overexpectation effect was expected to diminish with extensive AX-US trials, but only a nonsignificant tendency towards this effect was detected. Unfortunately, some of the results of Experiment 3 did not reach statistical significance. But combined with the results of Experiment 2, the present experiments suggest that overexpectation and extinction are not supported by the same mechanisms. Experiment 2 dissociated extinction from overexpectation through a manipulation that countered extinction but not overexpectation. In contrast, Experiment 3 tended to dissociate extinction from overexpectation in the other direction; that is extinction was enhanced whereas overexpectation was not. Collectively, Experiments 2 and 3 provide a double dissociation. Trivially, suppression in Group 8-X− of the present experiment was greater than suppression in Group X-20 (the comparable group from Experiment 2). The ambient humidity was greatly reduced during Experiment 3 relative to Experiment 2, which likely increased the effectiveness of the footshock and consequently enhanced responding to X.

5. General Discussion

The present experiments illuminated two important differences between the overexpectation and extinction effects. First, the results of Experiment 2 indicate that suppression controlled by the target stimulus (X) is enhanced by context postexposure following extinction but not overexpectation treatments. Second, Experiment 3 revealed that increasing the number of response degrading (Phase 2) trials from 8 to 40 affects suppression to X more after extinction than after overexpectation.

The present experiments provided a double dissociation between overexpectation and extinction. In principle, our results could instead reflect differences between renewal from overexpectation and renewal from extinction. Because testing was conducted outside of the training context, our results could reflect (posttraining context exposure and overtraining) dissociations between AAC renewal from overexpectation and AAC renewal from extinction. While we cannot categorically reject this interpretation, it seems unlikely that AAC renewal influenced our results. AAC renewal is exceedingly difficult to detect (e.g., Nakajima, Tanaka, Urushihara, and Imada, 2000). Moreover, if there were a dissociation in AAC renewal, the dissociation would be congruent with our conclusion that overexpectation and extinction are supported by different underlying processes. One might argue that this interpretive limitation of the present results could be avoided if we tested in the training context rather than in a neutral test context. Unfortunately, if testing were conducted in the training context, one could argue that our results reflected differential associative summation between the test context and the test CS. This is an especially important concern in situations in which the associative status of the context is manipulated, which was presumably the case in the present experiments.

The results of the present experiments are seemingly inconsistent with the view that overexpectation and extinction are empirically similar. Perhaps more importantly, they illuminate the mechanisms driving the two effects. Specifically, previous reports of similarity between overexpectation and extinction were interpreted as supportive of the assertion that the effects share a common mechanism: namely, a magnitude of outcome expectation that exceeds the magnitude of the outcome experienced (Rescorla and Wagner, 1972). According to this account extinction and overexpectation should be similarly affected by the manipulations employed in Experiments 1 and 2; thus, the present data were at least superficially inconsistent with this account. In contrast, the sometimes competing retrieval model (SOCR; Stout and Miller, 2007) asserts that overexpectation should be more similar to other compound conditioning deficits (e.g., blocking) than to extinction. However, this prediction was not supported by the results of Experiment 3, which suggest that overexpectation is not sensitive to extensive overtraining despite blocking and overshadowing being sensitive to similar manipulations. However, caution should be taken in interpreting this failure because the present experiments may have lacked the sensitivity to detect reduced overexpectation with extensive AX+ trials because of our selection of parameters that would favor observing enhanced extinction with the same manipulation. Future research should directly compare overexpectation with other compound conditioning effects.

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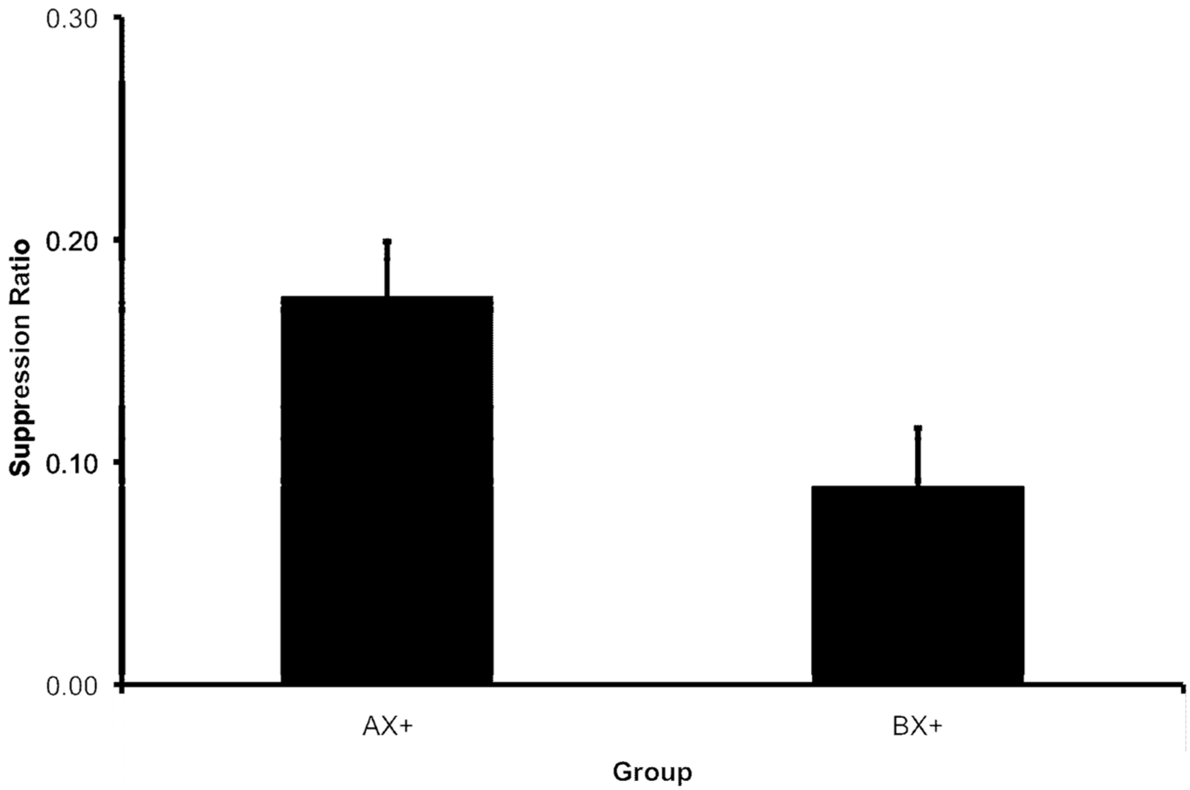

Figure 1.
Group mean suppression ratios in the presence of X in Experiment 1. See Table 1 and text for details. Lower values indicate stronger suppression and higher values indicate weaker suppression. The brackets represent standard errors of the means.

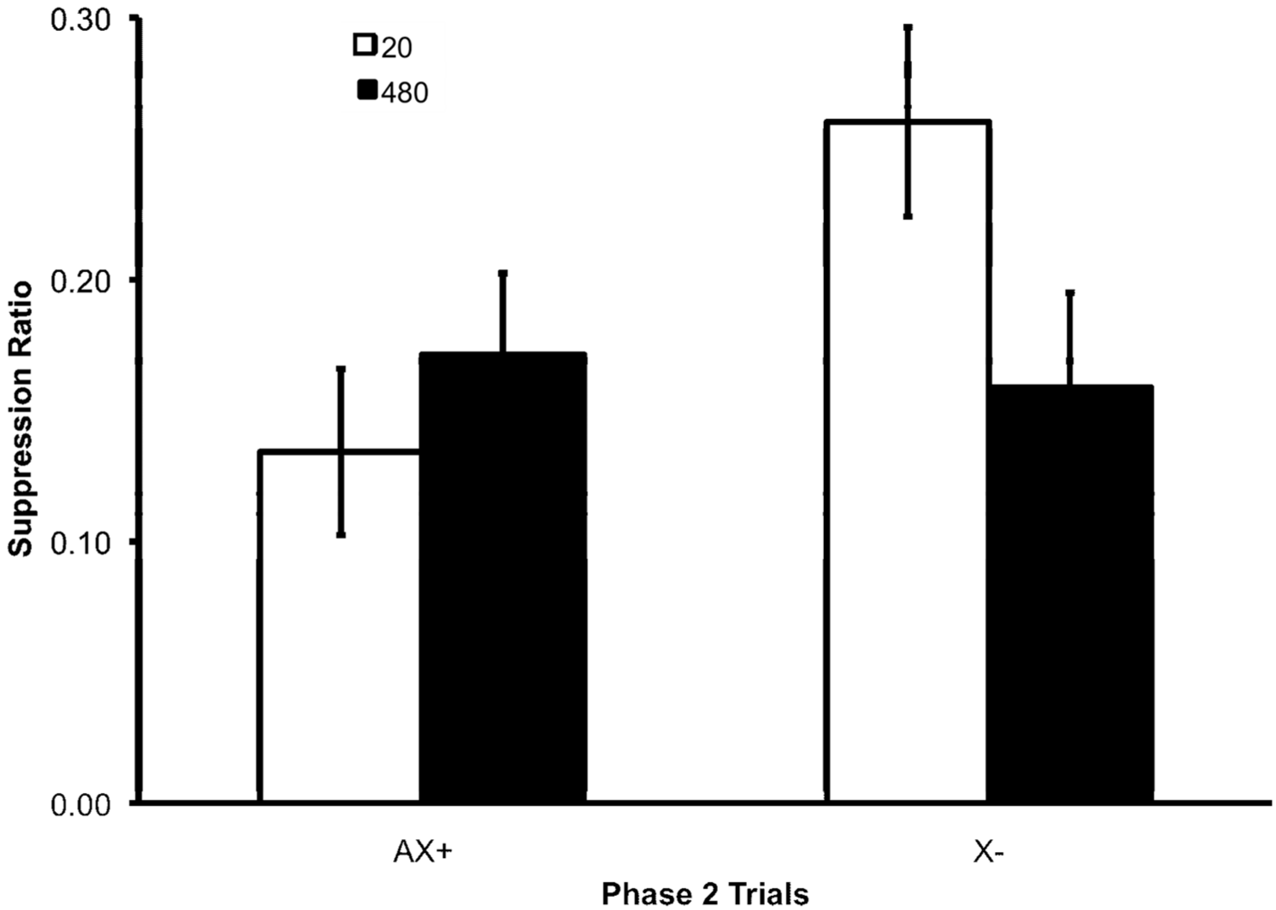

Figure 2.
Group mean suppression ratios in the presence of X in Experiment 2. See Table 2 and text for details. Lower values indicate stronger suppression and higher values indicate weaker suppression. The brackets represent standard errors of the means. The legend indicates the number of minutes of context exposure in Phase 3.

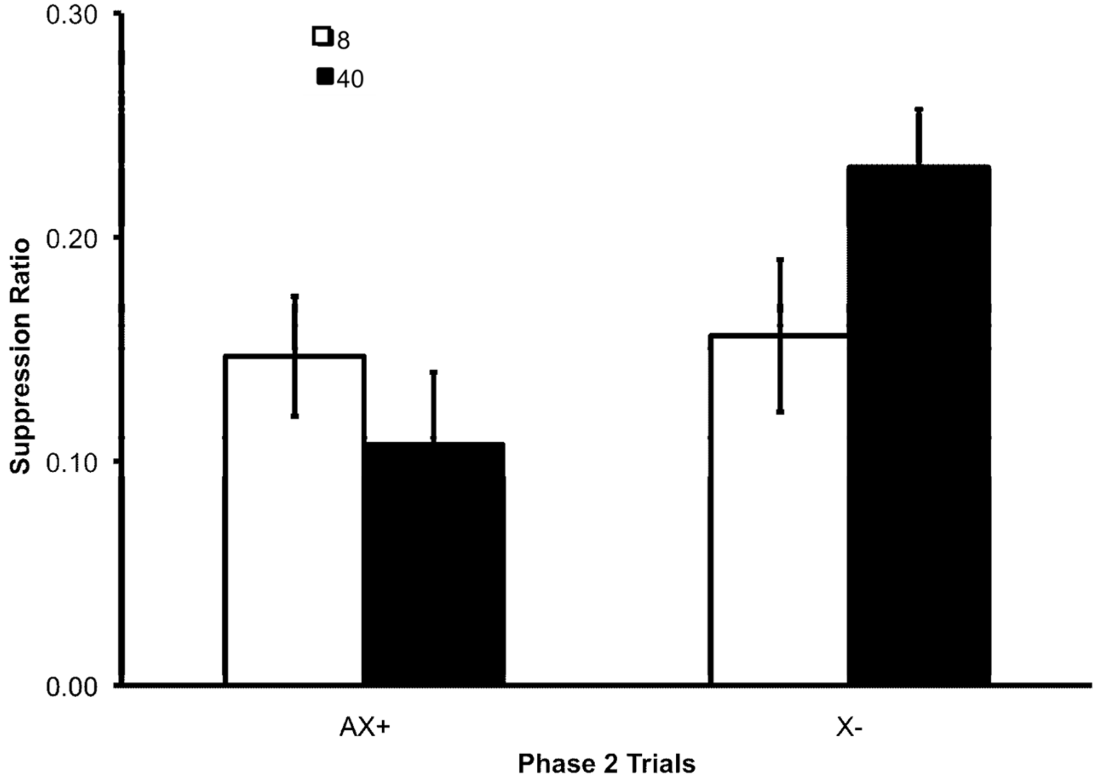

Figure 3.
Group mean suppression ratios in the presence of X in Experiment 3. See Table 3 and text for details. Lower values indicate stronger suppression and higher values indicate weaker suppression. The brackets represent standard errors of the means. The legend indicates the number Phase 2 trials.

Table 1

Design Summary of Experiment 1

Group	Phase 1	Phase 2	Test X
AX+	6 A+/6 X+	8 AX+	Cr
BX+	6 A+/6 X+	8 BX+	CR

Note: CSs A and B were a complex tone and a white noise exposure, counterbalanced within groups. CS X was a click train. All CSs were 10 s during training and 30 s during testing. The US (+) was a brief footshock. Slashes denote interspersed trials within sessions. CR (Cr) denotes a strong (intermediate) expected conditioned response based upon prior research. Training (Phases 1 and 2) was conducted in one context and testing was conducted in a physically distinct context.

Table 2

Design Summary of Experiment 2

Group	Phase 1	Phase2	Phase 3	Test X
AX+20	6 A+/6 X+	8 AX+	20 min	Cr
AX+80	6 A+/6 X+	8 AX+	480 min	Cr
X-20	6 A+/6 X+	8 X−	20 min	Cr
X-480	6 A+/6 X+	8 X−	480 min	CR

Note: CS A was a high frequency complex tone and CS X was a click train. All CSs were 10 s during training and 30 s during testing. The US (+) was a brief footshock. Slashes denote interspersed trials within sessions. CR (Cr) denotes a strong (intermediate) expected conditioned response based upon prior research. Training (Phases 1 and 2) was conducted in one context and testing was conducted in a physically distinct context.

Table 3

Design Summary of Experiment 3

Group	Phase 1	Phase 2	Test X
8-AX+	6 A+/6 X+	8 AX+	Cr
40-AX+	6 A+/6 X+	40 AX+	CR
8-X−	6 A+/6 X+	8 X−	Cr
40-X−	6 A+/6 X+	40 X−	cr

Note: CS A was a high frequency complex tone and CS X was a click train. All CSs were 10 s during training and 30 s during testing. The US (+) was a brief footshock. Slashes denote interspersed trials within sessions. CR (Cr) denotes a strong (intermediate) expected conditioned response based upon prior research. Training (Phases 1 and 2) was conducted in one context and testing was conducted in a physically distinct context.