Effects of Multiple Contexts and Context Similarity on the Renewal of Extinguished Conditioned Behavior in an ABA Design with Humans

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Abstract

The ABA renewal procedure involves pairing a conditional stimulus (CS) and an unconditional stimulus (US) in one context (A), presenting extinction trials of the CS alone in a second context (B), and nonreinforced test trials of the CS in the acquisition context (A). The renewal of extinguished conditioned behavior is observed during test. The current study tested the effects of multiple extinction contexts and context similarity in attenuating renewal. Participants (N = 99) took part in a fear conditioning ABA renewal procedure. Using a measure of self-reported expectancy of the US, ABA renewal was observed when a single extinction context that was dissimilar to the test context was used. Renewal was attenuated, though still present, when extinction occurred in multiple dissimilar extinction contexts or in a single extinction context that was similar to the test context. Renewal was completely abolished when multiple extinction contexts that were similar to the test context were combined. Multiple extinction contexts and context similarity act additively in their effect on attenuating renewal. The results are discussed in relation to the design of exposure therapy programs that seek to reduce relapse that can occur via renewal.

Keywords: Pavlovian conditioning; fear learning; extinction; renewal

Effects of Multiple Contexts and Context Similarity on the Renewal of Extinguished Conditioned Responses in an ABA Design with Humans

Pavlovian conditioning (Pavlov, 1927) is a learning process whereby an association is learnt between a conditional stimulus (CS) and an unconditional stimulus (US). Extinction treatment aims to reduce the conditioned response through repeatedly presenting the CS without the presence of the US. The clinical application of extinction treatment, known as exposure therapy, has been proven useful for the treatment of substance abuse disorders (Monti & Rohsenow, 1999) and various anxiety disorders (Deacon & Abramowitz, 2004). However, findings by researchers with non-human animal subjects (e.g., Bouton & Bolles, 1979; Dirikx et al., 2007) and human participants (e.g., Effting & Kindt, 2007; Neumann & Longbottom, 2008; Vansteenwegen, Dirikx, Hermans, Vervliet, & Eelen, 2006b) has shown that extinction does not abolish the underlying CS-US association, but reflects new and context specific learning. As a consequence, whether an individual will experience a return of conditioned responses or not may be dependent on whether the context evokes the original learning memory or the subsequent extinction learning memory. Although several associative-learning procedures may give rise to the return of conditioned responses, such as fear (for reviews see, Boschen, Neumann, & Waters, 2009; Bouton, 2002; Vansteenwegen, Dirikx, Hermans, Vervliet, & Eelen, 2006a), of special interest to the present research is the procedure termed renewal.

The renewal procedure typically involves three phases. In ABA renewal, CS-US pairings are given in context A during acquisition, extinction trials of the CS alone are given in context B, and test trials of the CS are given in context A. Conditioned responses that are reduced during extinction training in context B will be renewed during the test trials (Bouton & Bolles, 1979).

ABA renewal differs from other types of renewal such as ABC renewal in that the latter may evoke a conditioned response when the CS is presented in a third, novel context (context C). Further research to discover ways to reduce the renewal effect is important because it may show how to prevent relapse in certain circumstances following exposure therapy.

One possible method to promote retrieval of the extinction learning is to provide extinction treatment in a context in which the CS is likely to be encountered again (Thomas et al., 2003; Havermans et al., 2005). However, this approach will not necessarily abolish ABC or AAB renewal because the CS is encountered in a novel context. An alternative approach is to conduct exposure therapy in multiple contexts rather than one context in order to generalise extinction learning (Rowe & Craske, 1998). Chelonis, Calton, Hart, and Schachtman (1999) compared ABA renewal effects in a taste aversion task in groups of rats that were either given extinction treatment in multiple contexts, one context only, or not given extinction treatment at all. The group that was given extinction treatment in multiple contexts showed significantly less renewal of taste aversion than the other experimental groups. Gunther, Denniston, and Miller (1998) made a comparable finding in attenuating fear renewal in rats by conducting extinction in multiple contexts in an ABC design. Neumann (2006) extended this animal research to human participants in a series of experiments that used a computer based conditioned suppression task with both ABA and ABC renewal designs.

However, the apparently consistent finding of an attenuation of renewal following extinction in multiple contexts has been contradicted by subsequent research. Bouton, García-Guitiérrez, Zilskia, and Moody (2006) used a fear conditioning procedure with rats and did not find an attenuation of renewal. Thomas, Vurbic, and Novak (2009) also examined the effects of

multiple extinction contexts on renewal using a conditioned suppression task with rats. Extending the results of Bouton et al. (2006), they found that giving rats extinction treatment in three different contexts (in 36 trials) did not successfully attenuate renewal, but did so when combined with extended extinction trials (144 trials). The failure to find attenuation of renewal following extinction in multiple contexts is not restricted to the use of rat subjects. Neumann, Lipp, and Cory (2007) conducted two experiments using an aversive conditioning procedure with humans and found no attenuation of ABA renewal following extinction treatment in 3 or 5 different contexts.

In addition to the number of extinction trials (Thomas et al., 2009), the similarity between the contexts may be a factor that influences not only renewal itself, but also the effects of multiple extinction contexts on renewal. Thomas et al. (2003) tested the effects of context similarity in ABA, ABC, and AAB renewal designs using a fear conditioning procedure with rats. Although ABA renewal occurred in the first experiment when both odour and the location of the box were manipulated, it did not occur in the second experiment when each manipulation was used in isolation. Havermans et al. (2005) found analogous results in research with humans using a conditioned suppression task. Small contextual manipulations did not produce a significant renewal effect, although increasing the strength of the context change did. These results suggest that the effect of extinction on renewal may partially depend on the degree of contextual similarity between extinction training and subsequent testing. Extinction treatment in multiple contexts may thwart the renewal effect more readily when the multiple extinction contexts are more similar to the test context than when they are different. However, it is difficult to answer this question by examining past research due to differences in methodology. For example,

examining the extent of contextual similarity in the two prior contradictory human experiments (Neumann, 2006; Neumann et al., 2007) is complicated as neither study manipulated contexts systematically.

The aims of the present research were to investigate whether multiple extinction contexts and context similarity influence the magnitude of renewal both independently and in combination. A differential aversive conditioning procedure with humans was used to examine ABA renewal of shock US expectancy, similar to Neumann et al. (2007). Instead of the continuous US expectancy ratings used by Neumann et al., participants were probed to make a rating during selected CS presentations (see Lissek et al., 2008). Recently, Neumann and Kitlertsirivatana (2010) used this approach to measure US expectancy and demonstrated a renewal effect in both ABA and ABC designs. An advantage of the probed expectancy ratings is that it also permits the measurement of the time taken to make the ratings. Neumann and Kitlertsirivatana found that response times during an excitatory CS (i.e., CS+) and a control CS (i.e., CS-) decreased across trials within acquisition and extinction phases. Response times to both CSs increased whenever there was a change to a novel context from acquisition to extinction, although only the CS+ showed an increase in response time following a change to a novel context in the test phase. One interpretation of these results was that longer reaction times reflected increased ambiguity regarding the meaning of the CS in the novel context. On this basis, it would be expected that when extinction learning generalises to the test context, there will be less ambiguity regarding the meaning of the CS, and response times will be faster during the renewal test phase.

In contrast to prior research on multiple extinction contexts in which categorically distinct context manipulations were used (e.g., differed coloured lighting; Neumann, 2006; Neumann et

al., 2007), a continuous manipulation was used in the present experiment. This was achieved by varying the lighting level in the room from light to dark. Six groups were used. The ABA-d and ABA-s design renewal groups were exposed to one extinction context that was dissimilar or similar to the test context, respectively. The A(BCD)A-d and A(BCD)A-s design renewal groups were exposed to three extinction contexts that were dissimilar or similar to the test context, respectively. The AAA-d and AAA-s groups served as controls for the respective similar and dissimilar context groups and did not receive a change of context for the extinction trials. Based on previous findings, it was hypothesised that there will be attenuation in the renewal of US expectancy for the A(BCD)A-d group relative to the ABA-d group, thus showing that multiple extinction contexts attenuate renewal. It was also hypothesised that renewal would be attenuated in the ABA-s group when compared to the ABA-d group, thus showing that extinction in a similar context to test will attenuate renewal. Furthermore, it was hypothesised that there will be a complete abolishment of renewal in the A(BCD)A-s group (i.e., US expectancy during test will be identical to the AAA control groups), thus reflecting the additive effects of multiple extinction contexts and context similarity on renewal.

Method

Participants

One hundred and three first year psychology students from Griffith University participated in exchange for partial course credit. One participant did not make a response on 60% of the trials and three participants failed to show evidence of learning the stimulus contingencies during acquisition. These participants were removed from the analyses. The final sample consisted of 99 participants (32 males and 67 females) with a mean age of 23.24 years

(range = 18 to 49, *SD* = 5.51). Each participant was randomly assigned to one of six groups. The six groups included two control groups AAA-d (*n* =17), AAA-s (*n* = 17), and four experimental groups, ABA-d (*n* =17), ABA-s (*n* = 15), A(BCD)A-d (*n* = 16), and A(BCD)A-s (*n* = 17). Group membership was independent of gender, χ^2 (5) = .19, *p* = .60. All participants gave informed consent to a protocol granted institutional ethical approval prior to participation.

Apparatus

Participants completed the experiment in a 3 m x 3 m room and were monitored via a closed circuit-video camera from an adjoining room. The participants were seated 1.5 m away from a 1.8 m wide × 1.2 m high white screen. The CSs were projected on the screen by a Panasonic Model PT-L557E LCD projector. The CSs were pictures of two geometric shapes, a trapezoid (0.78 m high × 1.14 m wide) and a hexagon (0.83 m high × 0.94 m wide) shown as white outlines against a black background. The US was a 200 ms shock stimulus delivered to the participant's nonpreferred inner forearm via two disposable ADInstruments MLA1010B Ag/AgCl electrodes with varying intensity between participants. The shock stimulus was generated using an IWORX SI100 stimulus isolator that maintained a set current level and could emit a maximum of 100 volts. The DMDX program (Forster & Forster, 2003) run on a Dell Optiplex computer controlled the order and duration of the CS and US presentations and recorded the participants' responses.

The two response measures were self-reported expectancy of the shock and the time to make the expectancy ratings (see Lissek et al., 2008; Neumann & Kitlertsirivatana, 2010). After 1 s following the onset of selected CS presentations, the text *Likelihood of shock*? was presented above and below the CS in white Arial font (4 cm in height). The question cued the participants

to report their perceived expectation of the shock by pressing a button on the computer keyboard. Participants made ratings along a scale where 1 = *very low*, 2 = *low*, 3 = *moderate*, 4 = *high* using the V, B, N, and M keys, respectively, on the keyboard.

The context was manipulated by changing the lighting levels of the room using two Philips Soft White 100 watt light bulbs attached to the ceiling 2 m above the participant. The lighting level was varied using a Carrol & Meynell Ltd manually controlled dial. The light intensity could be varied from 0 to 139 lux. Nine different contexts were developed within the minimum and maximum values and were Context 1 = 0 lux, Context 2 = 0.1 lux, Context 3 = 0.8 lux, Context 4 = 3.8 lux, Context 5 = 12 lux, Context 6 = 27 lux, Context 7 = 53 lux, Context 8 = 89 lux, Context 9 = 139 lux. Similarity and dissimilarity between the contexts were thus defined as a continuous distance in lux value between the context/s presented during extinction and that presented during acquisition and test. The greater the distance in lux value between contexts, the greater the dissimilarity between them, and vice versa for similarity. To check for comparability across groups in depression, anxiety and stress levels, the Depression Anxiety Stress Scales 21-item version (DASS21, Lovibond & Lovibond, 2005) was used.

Procedure

Each participant was tested individually. After completing the DASS21, participants were seated in the experimental room and the intensity of the shock stimulus was set at a level the participant reported was “unpleasant, but not painful”. The mean shock level across all participants was 81.77 V (*SD* = 16.23). Participants were next told that they would be presented with geometric shapes and the shock stimulus and that they may notice changes in the lighting levels of the room. The participants were told that their task would be to report their level of

expectancy in receiving a shock when the text “Likelihood of shock?” appeared on the screen. They were asked to press the button on the keyboard corresponding to their level of expectancy using the index finger of their preferred hand. Moreover, participants were asked to provide their ratings as quickly as possible. The experiment began after the instructions.

Table 1 shows the number of participants in each group, contexts and corresponding lighting levels for each phase of the experiment for both the Dissimilar and Similar Context groups. All groups received context changes corresponding to the light intensity values for the manipulation of context similarity. In addition, the light intensity values assigned to each context were counterbalanced. The lighting levels for the AAA-d and ABA-d groups were level 1 (0 lux) or 9 (139 lux) for context A and level 7 (53 lux) or 3 (0.8 lux) for context B (context B was only used as contextual exposure alone for the AAA-d and AAA-s control groups). The lighting levels for the AAA-s and ABA-s groups were level 1 or 9 for context A and level 3 or 7 for context B (e.g., 0 lux and 0.8 lux). Lighting levels for the A(BCD)A-s and A(BCD)A-d were based on that used in the corresponding single extinction context groups. The A(BCD)A-s group used level 1 for context A and levels 2, 3, and 4 for contexts B to D or level 9 for context A and levels 6, 7, and 8 for contexts B to D. The A(BCD)A-d group used level 1 for context A and levels 6, 7, and 8 for contexts B to D or level 9 for context A and levels 2, 3, and 4 for contexts B to D.

Insert Table 1 about here

All groups received three phases of acquisition, extinction, and test and each phase began immediately after the previous one finished. In the acquisition phase, there were presentations of

the CS+ paired with the US and the CS- was presented alone. In the extinction phase, CS+ and CS- alone presentations were made. In the test phase, the CS+ and CS- were again presented alone. There were 10, 12 and 1 presentation of each CS in acquisition, extinction and test phases respectively, but participants were only prompted on selected trials to ensure that their response times were not affected by their ability to predict the expectancy rating prompts. The trials in which the ratings were prompted were trials 1, 4, 7 and 10 in the acquisition phase, trials 1, 4, 5, 8, 9 and 12 in the extinction phase, and for the single test trial. The order of CSs were randomised, with the restriction that the same CS was presented no more than two times in a row and that the first CS presented in each phase was counterbalanced across participants. The time between each trial was randomly varied between 10 s, 12.5 s, and 15 s CS offset to the next CS onset.

The ABA and A(BCD)A design groups received the extinction trials in a different context to acquisition, with the latter group receiving extinction trials across three contexts. In addition, the ABA and A(BCD)A design groups received exposure to context A alone after acquisition to partly control for the possibility that the context alone could serve as a cue of the US during the test phase (see Neumann & Longbottom, 2008). The AAA design groups received all CS presentations in the same context (context A), although this group also received exposures to the extinction context used in the corresponding ABA design groups (i.e., context B). The placement of the context alone exposures relative to the extinction trials is shown in Table 1. At the conclusion of the experiment, participants were asked if they had noticed a change in the lighting level of the room. All participants reported that they had noticed a change.

Scoring and Statistical Analyses

The shock expectancy ratings varied from 1 to 4. The participants were considered to have shown successful learning of the stimulus contingencies if they reported expectancy ratings of 3 or higher on the two last CS+ trials of the acquisition phase and expectancy ratings of 2 or below on the two last CS+ trials of the extinction phase. Three participants (two from ABA-s and one from A(BCD)A-d) were removed due to not learning the stimulus relationships during acquisition. Missing responses were replaced using linear interpolation of scores during the same experimental phase. Using this method, the mean of the participant's score preceding and/or following the missing score during the same experimental phase was used to replace the missing value. There were no missing data for either the first trial following or last trial immediately preceding the context changes made during extinction for the A(BCD)A-s or A(BCD)A-d groups. The percentage of missing responses across groups were: 2.14% for AAA-s, 1.60% for group AAA-d, 1.60% for group ABA-d, 2.14% for group ABA-s, 0.27% for group A(BCD)A-d and 1.87% for group A(BCD)A-s.

Oneway ANOVAs revealed no significant differences between the groups in final shock level, age, and scores on the depression, anxiety, and stress subscales of the DASS21, all Fs < 1.14, $p > .05$. Mixed model ANOVAs were used to test the hypotheses with the dependent variables of shock expectancy rating and response times. The between-subjects independent variables were Design with three levels (AAA, ABA, A(BCD)A) and Similarity with two levels (dissimilar, similar). The within-subjects independent variables were CS with two levels (CS+, CS-) and Trial with either 4 levels (acquisition) or 6 levels (extinction). In case of violations to the assumption of sphericity, Huynh-Feldt corrections were applied. Post hoc analyses used *t*

tests adjusted for Type I error using Bonferroni corrections. The statistical significance was set at an α-level of .05.

Results

Expectancy of Shock

The participants' expectancy ratings across all experimental phases in the dissimilar and similar contexts are shown in Figure 1 and Figure 2, respectively. Participants developed an expectancy of shock during acquisition, which was subsequently extinguished. A renewal of shock expectancy was found in the test phase in some renewal design groups, with its magnitude varying as a function of the number of extinction contexts and context similarity. Renewal was strongest when a single dissimilar context was presented during extinction and it appeared to be abolished when multiple similar contexts were presented during extinction.

Insert Figure 1 and 2 about here

Acquisition phase. A 3 × 2 × 2 × 4 (Design × Similarity × CS × Trial) ANOVA confirmed that participants learned to expect the shock after the CS+, but not after the CS-. This was shown by a significant main effect for CS, $F(1, 93) = 1318.81$, $p < .001$, $\eta_p^2 = .93$, a main effect for Trial $F(2, 207) = 110.68$, $p < .001$, $\eta_p^2 = .54$, and a CS × Trial interaction $F(2, 218) = 247.55$, $p < .001$, $\eta_p^2 = .73$. Multiple *t* tests showed that the shock expectancy did not differ between CS+ and CS- on Trial 1, $t(98) = 0.17$, $p = .70$, $d = .03$, but did differ on Trials 4, 7, and 10, all ts > 8.47, $p < .005$, $d > 1.71$.

A significant Design × CS interaction, $F(2, 93) = 3.95$, $p = .023$, $\eta_p^2 = .08$, suggested that the AAA, ABA and A(BCD)A designs differed in shock expectancy during the CSs. Further analyses revealed that the AAA design had a higher expectancy of the shock than the A(BCD)A design for the CS+, $t(65) = 2.72$, $p = .007$, $d = .07$. However, no further differences were found between any of the designs for the CS+ or CS-, all ts < 1.16, $p > .008$, $d < .29$. Further investigations revealed that there were no differences between the groups on expectancy of shock for the CS+ on the last acquisition trial, all $ts < 1.48$, $p > .18$, $d < 0.37$.

Last acquisition trial to first extinction trial. To investigate whether the change of context from the acquisition phase to the extinction phase affected expectancy ratings a 3 × 2 × 2 × 2 (Design × Similarity × CS × Trial) ANOVA was conducted. The Trial factor used the last acquisition trial and first extinction trial. The analyses revealed a significant main effect of CS $F(1, 93) = 2641.39$, $p < .001$, $\eta_p^2 = .97$, a significant main effect of Trial $F(1, 93) = 7.84$, $p = .006$, $\eta_p^2 = .08$, a significant CS × Trial interaction $F(1, 93) = 29.80$, $p < .001$, $\eta_p^2 = .24$, a significant Design × CS interaction $F(1, 93) = 4.48$, $p = .01$, $\eta_p^2 = .09$, and a significant Design × CS × Trial interaction $F(2, 93) = 3.87$, $p = .02$, $\eta_p^2 = .08$. To further investigate the three-way interaction, t tests were conducted by comparing between the acquisition and extinction trials separately for the CS+ and CS- and each design type. There was no significant difference between the last acquisition trial and the first extinction trial for any of the designs for the CS+, all ts < .17, $p > .09$, $d < 0.06$. Furthermore, there were no significant differences between trials for the CS- for the AAA design, $t(33) = .90$, $p = .90$, $d = 0.31$. However, for the ABA and A(BCD)A designs there was a significant increase in the participants' expectancy of shock for the CS- from the last

acquisition trial to the first extinction trial, both *t*s > 2.96, $p < .008$, $d > 1.03$. This showed a lack of transfer of learning following a change of context for the CS-.

Extinction phase. A 3 × 2 × 2 × 6 (Design × Similarity × CS × Trial) ANOVA for the extinction trials showed a main effect for CS, $F(1, 93) = 291.77$, $p < .001$, $\eta_p^2 = .76$, a main effect for Trial, $F(4, 368) = 219.15$, $p < .001$, $\eta_p^2 = .70$, and a CS × Trial interaction, $F(4, 367) = 125.74$, $p < .001$, $\eta_p^2 = .58$. Post hoc analyses confirmed extinction by showing that there was a significantly higher expectancy of the shock during the CS+ than the CS- on Trials 1 and 4, both *t*s > 3.54, $p < .001$, $d > 0.72$, but not on Trials 5 to 12, all *t*s < 2.48, $p > .01$, $d < 0.50$.

The analyses also showed a significant Design × CS × Trial interaction $F(10, 465) = 2.87$, $p = .002$, $\eta_p^2 = .09$. Multiple *t* tests were conducted on the CS+ and CS- separately comparing each Trial to the subsequent Trial in each design. No significant differences were found for the CS- between any of the Trials for any of the designs, all *t*s < 2.42, $p > .002$, $d < 0.84$. For the CS+, the expectancy of shock ratings significantly decreased from Trial 1 to Trial 4, and again to Trial 5 for the AAA design, both *t*s > 3.42, $p < .002$, $d > 1.19$. There was a significant decline in expectancy between Trial 1 and Trial 4 for the ABA designs $t(32) = 6.63$, $p < .002$, $d = 2.34$. For the A(BCD)A designs, there was a significant decline in expectancy between Trial 1 and Trial 4, $t(31) = 9.37$, $p < .001$, $d = 3.37$, no difference between Trial 4 and Trial 5, $t(31) = .73$, $p > .003$, $d = 0.09$, a significant decline between Trial 5 and Trial 8, $t(31) = 3.01$, $p = .002$, $d = 1.08$, and no further significant differences between Trials 8, 9, and 12, both *t*s < .91, $p > .003$, $d < 0.03$. This suggests that expectancy of shock in the A(BCD)A designs decreased from Trial 1 to 4, but that this decrease ceased with the presentation of a new extinction context immediately before Trial 5. The decrease in expectancy again resumed during subsequent presentations of extinction contexts.

Last extinction trial to test trial. The first test for renewal used a 3 × 2 × 2 × 2 (Design × Similarity × CS × Trial) ANOVA comparing the last extinction trial to the first test trial. Analyses revealed that all main effects and interactions were significant[1] and subsumed under a significant Design × Similarity × CS × Trial interaction, $F(2, 93) = 3.43$, $p = .036$, $\eta_p^2 = .07$. The interaction was examined by comparing the last extinction trial and test trial for each group and CS. The analyses yielded no differences between the trials for the CS- in any group, all *t*s < .03, $p > .73$, $d < 0.02$. A significant increase in expectancy ratings from the last extinction trial to the test trial for the CS+ was found in each of the ABA-d, ABA-s and A(BCD)A-d groups, all *t*s > 7.14 , $p < .001$, $d > 3.57$. However, there was no significant change in the participants' expectancy ratings for the CS+ in the AAA-d, AAA-s and A(BCD)A-s groups, all *t*s < .63, $p > .50$, $d < 0.03$. A renewal effect was thus present in the ABA-d, ABA-s and A(BCD)A-d groups. No renewal was present in the A(BCD)A-s group.

Test phase. The second test for renewal examined expectancy on the test trials only with a 3 × 2 × 2 (Design × Similarity × CS) ANOVA. Analyses revealed that all significant main effects and interactions[2] were subsumed under a significant Design × Similarity × CS interaction, $F(2, 93) = 3.69$, $p = .03$, $\eta_p^2 = .07$. An investigation of the three-way interaction was conducted testing for differences between the CS+ and CS- separately for each group. The analyses revealed that there was a significantly higher expectancy rating for the CS+ than the CS- in the ABA-d, ABA-s and A(BCD)A-d groups, all *ts* > 4.61, $p < .003$, $d > 2.03$. However, there was no significant difference between the CS+ and CS- in the AAA-d, AAA-s and A(BCD)A-s groups, all *ts* < .44, $p > .66$, $d < 0.22$. Again, these results show that a renewal effect was thus present in the ABA-d, ABA-s and A(BCD)A-d groups and not the A(BCD)A-s group.

Further investigation of the three-way interaction was done to test for differences between groups for each CS. Analyses showed that there were no differences between the groups for the CS-, all *t*s < .25, $p > .80$, $d < 0.09$. However, for the CS+ the A(BCD)A-d group had a significantly lower expectancy rating than the ABA-d group, $t(31) = 3.98$, $p < .001$, $d = 1.43$, and the A(BCD)A-s group had a significantly lower expectancy rating than the ABA-s group, $t(31) = 5.23$, $p < .001$, $d = 1.88$. These analyses confirmed the attenuation of renewal with multiple extinction contexts. The analyses also revealed that the ABA-s group had a significantly lower shock expectancy for the CS+ than the ABA-d group, $t(30) = 3.62$, $p < .001$, $d = 1.32$. Furthermore, the A(BCD)A-s group had a significantly lower expectancy than the A(BCD)A-d group, $t(31) = 4.87$, $p < .001$, $d = 1.75$. These analyses confirmed the attenuation of renewal when the extinction context is similar to the test context.

Response Time

The participants' response times for the first and last trials in the acquisition and extinction phases and for the test trial are shown in Table 2. As can be seen, response times decreased within each phase for acquisition and extinction. In addition, the response times in the renewal design groups increased from the last acquisition trial to the first extinction trial. Response times decreased from the extinction to test phase for the control groups and similar context renewal design groups, but tended to increase in the test phase for the renewal design groups with dissimilar contexts.

Insert Table 2 about here

Acquisition phase. A 3 × 2 × 2 × 4 (Design × Similarity × CS × Trial) ANOVA yielded a significant main effect of Trial, $F(3, 279) = 35.19$, $p < .001$, $\eta_p^2 = .28$. The main effect of Trial reflected that response time shortened over trials. A comparison between the first acquisition trial and last acquisition trial confirmed this impression with a significant difference, $t(98) = 7.13$, $p < .001$, $d = 1.44$.

Last acquisition trial to first extinction trial. A 3 × 2 × 2 × 2 (Design × Similarity × CS × Trial) ANOVA examined the effects of the context change from the acquisition phase to the extinction phase. The analyses revealed a main effect of Trial, $F(1, 93) = 4.16$, $p = .04$, $\eta_p^2 = .04$, and a significant Design × Trial interaction, $F(2, 93) = 9.34$, $p < .001$, $\eta_p^2 = .17$. Post hoc analyses showed that there was no significant difference between the last acquisition trial and the first extinction trial for the AAA design, $t(33) = 2.47$, $p = .18$, $d = 0.86$. However, there was a significant slowing from the last acquisition trial to the first extinction trial for the ABA design, $t(31) = 2.53$, $p = .016$, $d = 0.90$, and A(BCD)A design, $t(32) = 3.85$, $p < .001$, $d = 1.36$. The change of context that was experienced only by the ABA and A(BCD)A design groups thus increased response times.

Extinction phase. A 3 × 2 × 2 × 6 (Design × Similarity × CS × Trial) ANOVA yielded a main effect for CS, $F(1, 93) = 4.62$, $p = .03$, $\eta_p^2 = .05$, and a Design × CS interaction, $F(2, 93) = 3.72$, $p = .03$, $\eta_p^2 = .07$. Post hoc tests revealed a significantly shorter response time for the CS- than the CS+ for the AAA design $t(33) = 3.51$, $p < .001$, $d = 1.22$, whereas there were no differences between the CS+ and CS- for the ABA and A(BCD)A designs, both ts < .87, $p > .44$, $d < 0.30$.

The analyses also indicated that response times decreased across the extinction phase as shown by a main effect for Trial, $F(5, 440) = 16.24$, $p < .001$, $\eta_p^2 = .15$. Comparisons confirmed that response times were shorter on trial E1 than on trial E12, $t(98) = 3.60$, $p < .001$, $d = 0.73$. A Design × Trial interaction $F(10, 440) = 4.57$, $p < .001$, $\eta_p^2 = .09$ was also found. Further *t* tests showed no significant differences between the trials for the ABA design, all *t*s < 2.48, $p > .003$, $d < 0.86$. For the A(BCD)A design, there was a significant shortening between Trial 5 and Trial 8, $t(32) = 2.94$, $p = .003$, $d = 1.02$, but no further comparisons were significant, all *t*s < 2.46, $p > .003$, $d < 0.86$. For the AAA design there was a significant lengthening in response time between Trial 1 and Trial 4, $t(31) = 5.02$, $p < .001$, $d = 1.75$, and a significant shortening between Trial 4 and Trial 5, $t(31) = 6.03$, $p < .001$, $d = 2.10$.

Last extinction trial to test trial. Participants' response times for the last extinction trial to the test trial were investigated using a 3 × 2 × 2 × 2 (Design × Similarity × CS × Trial) ANOVA. The analysis revealed a significant main effect of Design, $F(2, 93) = 3.87$, $p = .024$, $\eta_p^2 = .08$, and a significant Design × Trial Interaction $F(2, 93) = 6.49$, $p = .002$, $\eta_p^2 = .12$. The interaction was examined by comparing across trials for each design and showed that for the AAA design there was a significant shortening in response time from the last extinction trial to the test trial, $t(33) = 3.56$, $p < .001$, $d = 1.23$. However, no differences between trials were found for the ABA and A(BCD)A designs, both *t*s < 0.88, $p > .37$, $d < 0.31$.

The analyses also revealed a significant Similarity × Trial interaction, $F(2, 93) = 6.71$, $p = .011$, $\eta_p^2 = .07$. Post hoc analyses showed that there was no significant difference between the last extinction trial and the test trial for the dissimilar context, $t(49) = 0.74$, $p = .46$, $d = 0.21$.

However, there was a significant shortening in response time from the last extinction trial to the test trial for the similar context, $t(48) = 2.75$, $p < .001$, $d = 0.79$.

Test phase. To further investigate the participants' response times during the test phase a 3 × 2 × 2 (Design × Similarity × CS) ANOVA was conducted. The analyses revealed a significant main effect of CS, $F(1, 93) = 4.43$, $p = .038$, $\eta_p^2 = .05$, a significant main effect of Similarity, $F(1, 93) = 4.51$, $p = .036$, $\eta_p^2 = .05$, and a significant main effect of Design, $F(2, 93) = 8.49$, $p < .001$, $\eta_p^2 = .15$. The CS main effect showed that the participant's response times were significantly longer for the CS + than the CS-. The main effect of Similarity showed that the participants in the similar context had a shorter response time than the participants in the dissimilar context. Further investigation of the main effect of design revealed that the participants in the AAA design had a significantly shorter response time than the participants in the ABA and A(BCD)A designs, both ts > 5.69, $p < .001$, $d > 1.15$, which themselves did not differ, $t(98) = .88$, $p > .52$, $d = 0.18$. The change to the test context thus slowed response times with the slowing being more pronounced for a dissimilar context.

Discussion

The aim of the present experiment was to test the individual and combined effects of conducting extinction in multiple contexts and in a single context that is similar to the test context on ABA renewal. Renewal was tested by comparing the change in expectancy from the last extinction trial to the test trial for the CS+ and by comparing expectancy to the CS+ and CS- on the test trial. The results confirmed the hypotheses that renewal would be present, but attenuated, for the A(BCD)A-d and ABA-s groups where extinction was conducted in multiple dissimilar contexts or a single similar context to test, respectively. It was also expected that for the

A(BCD)A-s group, where the effects of multiple extinction contexts and context similarity were combined, a complete abolishment of ABA renewal would occur. This hypothesis was also confirmed. The present results thus show that giving extinction in multiple contexts will not necessarily lead to an abolishment of renewal. The amount of attenuation, if present, may depend on other variables operating in the experiment. Like the number of extinction trials that are used (Thomas et al., 2009), the similarity between the extinction and test context is one such variable that influences the effect of extinction treatment in multiple contexts.

The observation of a reliable renewal effect in the ABA-d and ABA-s groups provided a means to test the hypothesis that renewal would be attenuated when extinction treatment is given in multiple contexts. Comparisons between the ABA-d and ABA-s single extinction context groups to the A(BCD)A-d and A(BCD)A-s multiple extinction context groups, respectively, revealed lower US expectancy ratings in the multiple extinction context groups for the CS+. No differences were found between the groups in the CS- control stimulus. These results are consistent with research conducted by Gunther et al. (1998), Chelonis et al. (1999), and Neumann (2006), who found that extinction treatment in multiple contexts attenuated renewal in an ABA and/or ABC designs. However, they are inconsistent with the findings of Bouton et al. (2006) and Neumann et al. (2007) where an attenuation of renewal was not found. Neumann et al. used a fear conditioning procedure with humans and a US expectancy measure in highly dissimilar contexts that differed in the colour of the background light and type of sound in the room. The present experiment employed only variations in the level of lighting in the room. Based on the present observation that renewal following multiple extinction contexts is larger when the contexts are highly dissimilar (i.e., compare A(BCD)A-s with A(BCD)A-d), it can be suggested that the

inconsistencies between the current study and that of Neumann et al. can be accounted for by differences in the contextual manipulations used.

The hypothesis that renewal will be smaller when the extinction context is more similar to the test context was examined by comparing the groups that received dissimilar and similar contexts. No differences were found between the groups for the CS- during test. The lower expectancy of the US during the CS+ for the ABA-s group compared to the ABA-d group, and the A(BCD)A-s group compared to the A(BCD)A-d group confirmed that extinction more readily generalises to test when similar contexts are used compared to dissimilar contexts. The current research is consistent with previous nonhuman animal research conducted by Thomas et al. (2003) and research conducted on humans by Havermans et al. (2005) who found reduced renewal effects when small contextual manipulations were made. The present experiment, however, used a more systematic manipulation of context similarity in which the lighting level of the room was varied along a continuous scale.

The final hypothesis was that there will be a complete abolishment of renewal when extinction treatment is given in multiple extinction contexts which are similar to the acquisition and test context. The hypothesis was confirmed in that the A(BCD)A-d group increased in US expectancy from the last extinction trial to the test trial for the CS+, whereas the A(BCD)A-s group did not. Indeed, the same pattern of results during test was found for the A(BCD)A-s group as was found for the AAA-s and AAA-d control groups. These findings are consistent with research that has used a combination of multiple extinction contexts and extended extinction training to abolish renewal in rats (Thomas et al., 2009). Thomas et al. (2009) suggested that the use of one manipulation alone is not enough to fully abolish renewal and that the different

contextual manipulations may have had an additive attenuating effect that successfully abolished renewal. It is plausible that the same additive effect produced abolishment of renewal in the A(BCD)A-s group in the present experiment.

Bouton's (1988) memory model of extinction suggests that contexts presented during extinction treatment have cues that are shared from one context to the other. Subsequently, extinction treatment in multiple contexts provides greater overlap between these shared cues compared to extinction in a single extinction context. This allows for extinction to be more readily generalised from the extinction phase to the test phase hence resulting in attenuation of renewal. Furthermore, the model suggests that extinction treatment in a context which is similar to the test context will increase the likelihood that the CS-noUS association is retrieved. Because there remains ambiguity about the meaning of the CS following extinction, the degree of similarity between the extinction and test context will determine the amount of renewal found. The added effects of the multiple extinction contexts and similar contexts on the extinction treatment seem to have become strong enough to promote the retrieval of the CS-noUS association and generalise extinction learning from extinction to test, resulting in the complete abolishment of renewal. The present findings support an explanation derived from Bouton's memory model of extinction for why multiple extinction contexts and similar contexts can attenuate renewal in isolation and abolish it completely when combined.

Another finding that deserves some attention is the increase in expectancy ratings from the last acquisition trial to the first extinction trial for the A(BCD)A and ABA Designs for the CS-. The increase in expectancy appears to reflect a generalisation decrement of conditioned inhibition for the CS- following a change of context on the extinction trial. The context change

may have resulted in increased ambiguity regarding the nature of the CS-noUS association and an increase in expectancy of the US for the CS-. Bouton, (2004) noted that in some cases the first thing learnt may, to an extent, be context specific, which may explain for the increases in expectancy ratings for the CS- following the context change. In most cases, the first thing learnt about a CS is an excitatory CS-US association. In this respect, the relatively good transfer of acquisition learning for the CS+ differs from the decrement seen for the CS-. The greater transfer of learning following a context change from acquisition to extinction for the CS+ than for the CS- has also been observed in other research (e.g., Effting & Kindt, 2007; Neumann et al., 2007; cf. Neumann, 2007). It would appear that, at least for a human differential conditioning procedure, the transfer of learning across contexts is less stable for a CS- than for a CS+.

Response times to make the US expectancy ratings were used as a secondary measure related to learning. The response times revealed a shortening from earlier to later trials in both the acquisition and extinction phase. Lissek et al. (2008) argued that response times vary as a function of ambiguity surrounding the CSs; indeed a similar interpretation was also provided by Neumann & Kitlertsirivatana (2010) in a more recent study using the same measures of response time as the current study. These interpretations are supported by the fact that the shortening of response times within a phase was paralleled by the change in expectancy judgements. That is, participant's expectancy became not only faster, but more accurate to the actual stimulus contingencies over successive trials.

Response times were also influenced by the changes in context. A change in context from acquisition to extinction lengthened response times in the ABA and A(BCD)A design groups. This lengthening was paralleled by an increase in US expectancy for the CS-, although no change

in expectancy was observed for the CS+ following the context change between acquisition and extinction. The change in context between extinction and test did not directly influence response times in the ABA and A(BCD)A design groups, although it did negate the shortening in response time that occurred with the AAA design. Supporting this result was an overall shorter response time on the test trial for the AAA design group than the ABA and A(BCD)A design groups. The US expectancy judgements did not change from extinction to test for the AAA design, but they did change for the ABA design groups and the A(BCD)A-d design group. These parallels between the response time and expectancy judgements, though not perfect, do suggest that they reflect similar underlying learning processes. Changes in US expectancy that are created by contextual changes tend to be associated with a lengthening in response times.

Dirikx, Hermans, Vansteenwegen, Baeyens, and Eelen (2004) also used response time during a conditioning experiment, although the response time was measured as the time taken to respond to a secondary probe stimulus. They suggested that a lengthening in response time reflected an increased allocation of processing resources towards the CS. This interpretation is not necessarily inconsistent with the notion that response times in the present experiment reflect the ambiguity associated with the CS. A more ambiguous CS would be expected to be allocated more processing resources in order to determine its meaning than would be an unambiguous CS.

The present findings have application for the use of exposure therapy in the treatment of various anxiety disorders. The results overall indicate that conducting exposure therapy in several different contexts will not necessarily abolish relapse via a renewal effect. Likewise, conducting exposure therapy in a context which is only similar to that in which the feared object is subsequently encountered may attenuate but not necessarily abolish renewal. Both have the

potential to thwart renewal but they are dependent on other factors that may operate in a given situation. The results suggest that clinicians should use a combination of strategies to reduce the risk of relapse because a single strategy on its own may not have enough impact. The present results suggest that a combination of both multiple extinction context and context similarity should be used to increase the likelihood that relapse will be avoided. Moreover, increasing the number of extinction trials (Thomas et al. 2009) may also ensure the long term success of exposure therapy.

The present study is limited in that it only measured fear indirectly via self reported measures of shock expectancy. Expectancy of the shock US was selected because it has proven to be the most sensitive measure of renewal in a fear conditioning procedure (e.g., Effting & Kindt, 2007; Neumann et al., 2007) and would thus be more likely to be sensitive to the subtle manipulations of context similarity and the use of multiple extinction contexts in the present experiment. However, a measurement of the expectancy of the US does reduce its application to, for instance, phobias where fear as an affective reaction is a central component. Self report measures of shock expectancy are correlated with objective measures of fear, such as the startle response (Neumann & Waters, 2006). Measuring startle responses in conjunction with measures of the autonomic nervous system, such as skin conductance responses (e.g., Lipp, Neumann, & Mason, 2001; Neumann, Lipp, & Siddle, 1997; Neumann, Waters, & Westbury, 2008), is recommended for future research to provide a more objective and valid measure of fear learning than that provided by expectancy ratings alone.

In summary, the current research found that the use of multiple extinction contexts attenuates renewal, providing further support to the Chelonis et al. (1999), Gunther et al. (1988)

and Neumann (2006) studies, which found similar results. The current study also supports the suggestions by Thomas et al. (2003) and Havermans et al. (2005) that the use of similarity across contexts may attenuate renewal. The combined effect of multiple extinction contexts and similar extinction contexts seem strong enough to abolish renewal altogether. The present findings give hope to the future application of behavioural principles in the treatment of substance abuse and anxiety disorders. Relapse via a renewal effect may not necessarily be an inevitable consequence of the context dependent nature of extinction learning. A carefully designed exposure treatment program, that is informed by empirical research such as that conducted here, has the potential to reduce the chance of relapse following treatment.

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Footnotes

[1]Significant main effect of CS $F(1, 93) = 73.00$, $p < .001$, $\eta_p^2 = .44$, a significant main effect of Trial $F(1, 93) = 72.13$, $p < .001$, $\eta_p^2 = .44$, a significant main effect of Design $F(2, 93) = 25.98$, $p < .001$, $\eta_p^2 = .36$, a significant main effect of Similarity $F(1, 93) = 12.75$, $p = .001$, $\eta_p^2 = .12$, a significant CS × Design interaction $F(2, 93) = 31.00$, $p < .001$, $\eta_p^2 = .40$, a significant Design × Similarity interaction $F(2, 93) = 3.46$, $p = .035$, $\eta_p^2 = .07$, a significant CS × Similarity interaction $F(1, 93) = 11.71$, $p = .001$, $\eta_p^2 = .11$, a significant Trial × Design interaction $F(2, 93) = 29.65$, $p < .001$, $\eta_p^2 = .39$, a significant Trial × Similarity interaction $F(2, 93) = 10.30$, $p = .001$, $\eta_p^2 = .10$, a significant CS × Trial interaction $F(1, 93) = 67.74$, $p < .001$, $\eta_p^2 = .42$, a significant CS × Trial × Design interaction $F(2, 93) = 25.26$, $p < .001$, $\eta_p^2 = .35$, a significant CS × Trial × Similarity interaction $F(1, 93) = 10.56$, $p = .002$, $\eta_p^2 = .10$.

[2]Significant main effect of Design $F(2, 93) = 28.35$, $p < .001$, $\eta_p^2 = .38$, a significant main effect of Similarity $F(1, 93) = 12.96$, $p = .001$, $\eta_p^2 = .12$, a significant main effect of CS $F(1, 93) = 72.69$, $p < .001$, $\eta_p^2 = .44$, a significant Design × CS interaction $F(2, 93) = 30.16$, $p < .001$, $\eta_p^2 = .39$, a significant Similarity × CS interaction $F(1, 93) = 11.50$, $p = .001$, $\eta_p^2 = .1.1$.

Table 1.

The Contexts Changes and Lighting Levels used for Each Phase of the Experiment in the Dissimilar and Similar Context groups (N = 112).

Experiment Phase	Dissimilar Context Groups						Similar Context Groups					
	AAA-d		ABA-d		A(BCD)A-d		AAA-s		ABA-s		A(BCD)A-s	
Acquisition	(A) 1	(A) 9	(A) 1	(A) 9	(A) 1	(A) 9	(A) 1	(A) 9	(A) 1	(A) 9	(A) 1	(A) 9
Context exposure 1	(B) 7	(B) 3	(A) 1	(A) 9	(A) 1	(A) 9	(B) 3	(B) 7	(A) 1	(A) 9	(A) 1	(A) 9
Extinction 1	(A) 1	(A) 9	(B) 7	(B) 3	(B) 6	(B) 4	(A) 1	(A) 9	(B) 3	(B) 7	(B) 2	(B) 8
Context exposure 2	(B) 7	(B) 3	(A) 1	(A) 9	(A) 1	(A) 9	(B) 3	(B) 7	(A) 1	(A) 9	(A) 1	(A) 9
Extinction 2	(A) 1	(A) 9	(B) 7	(B) 3	(C) 7	(C) 3	(A) 1	(A) 9	(B) 3	(B) 7	(C) 3	(C) 7
Context exposure 3	(B) 7	(B) 3	(A) 1	(A) 9	(A) 1	(A) 9	(B) 3	(B) 7	(A) 1	(A) 9	(A) 1	(A) 9
Extinction 3	(A) 1	(A) 9	(B) 7	(B) 3	(D) 8	(D) 2	(A) 1	(A) 9	(B) 3	(B) 7	(D) 4	(D) 6
Test	(A) 1	(A) 9	(A) 1	(A) 9	(A) 1	(A) 9	(A) 1	(A) 9	(A) 1	(A) 9	(A) 1	(A) 9

Note: A, B, C, D = the different contexts of the experiment. Participants in each group were counterbalanced between maximum darkness of (1) or maximum light (9) in acquisition and test with a minimum of 7 participants in each counterbalanced condition. Due to this counterbalancing, the contexts presented during the context exposure and extinction phases differed between the counterbalanced conditions in each group. The two counterbalanced conditions for each group are shown in the table. The presentation order of contexts B, C, and D for the multiple extinction groups were randomized across participants to control for the effects of the order of lighting (only one order is shown in this table for clarity). Numbers 1 to 9 = lighting levels. Lighting level 1 = 0 lux, 2 = 0.1 lux, 3 = 0.8 lux, 4 = 3.8 lux, 5 = 12 lux, 6 = 27 lux, 7 = 53 lux, 8 = 89 lux, 9 = 139 lux.

Table 2.

Mean Response Time (ms) to the First and Last Trials in the Acquisition and Extinction Phases and for the Test Trial in Each Group (standard deviations are in parentheses)

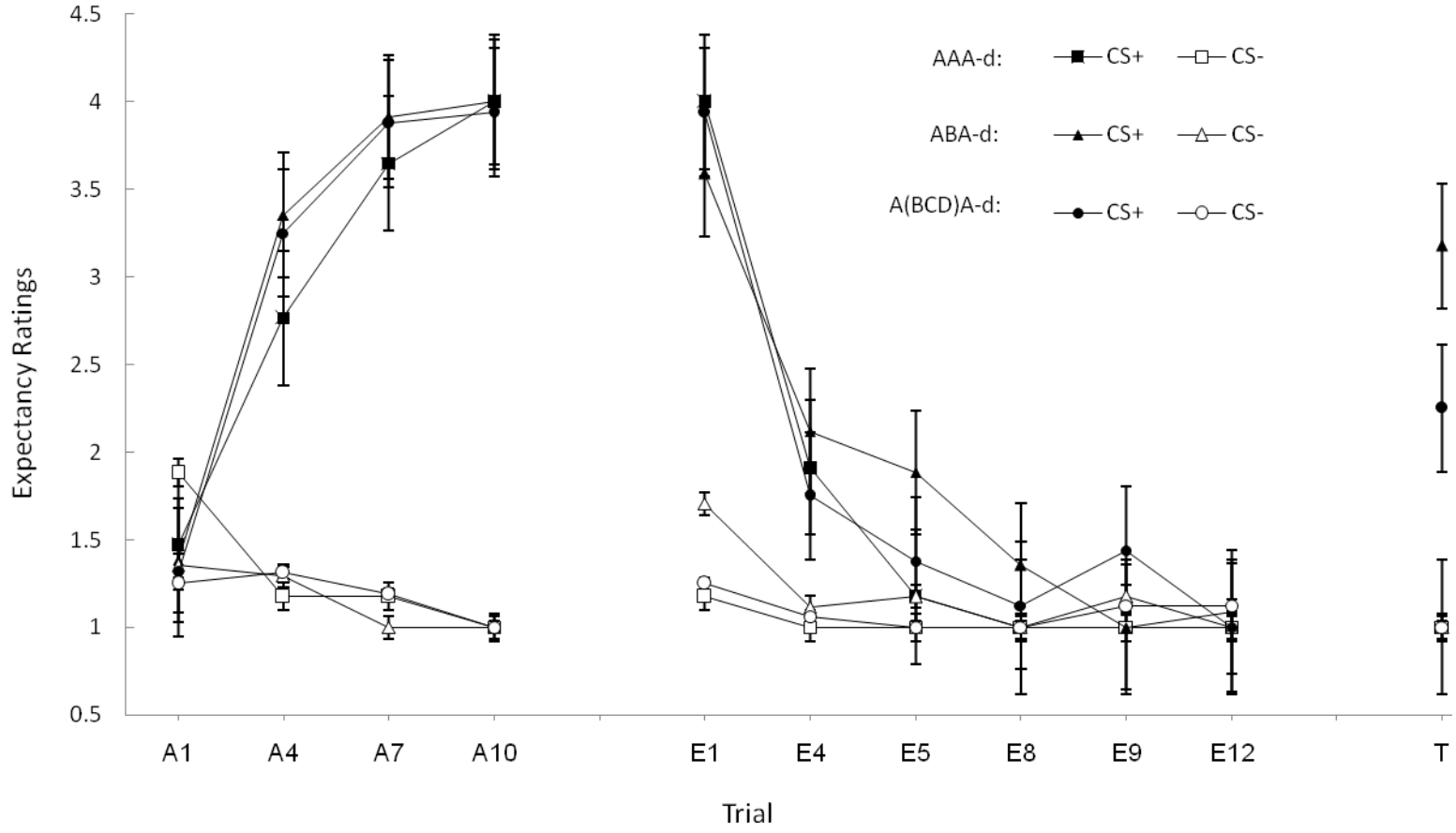
Group	CS	Experiment Phase and Trial				
		A1	A10	E1	E12	Test
Dissimilar Context Groups						
AAA-d	CS+	1363 (777)	1314 (962)	863 (383)	966 (570)	661 (271)
	CS-	1379 (992)	1201 (660)	1097 (1142)	835 (327)	677 (256)
ABA-d	CS+	1923 (738)	988 (403)	1310 (624)	896 (398)	1307 (627)
	CS-	1865 (1089)	1170 (627)	1343 (637)	1175 (617)	1015(527)
A(BCD)A-d	CS+	1890 (111)	1265 (707)	1457 (937)	987 (487)	1408 (832)
	CS-	2221 (900)	1296 (894)	1772 (1135)	1004 (412)	1162 (661)
Similar Context Groups						
AAA-s	CS+	1978 (1186)	1140 (464)	1328 (809)	1102 (555)	694 (397)
	CS-	1849 (879)	1481 (884)	897 (428)	893 (388)	677 (305)
ABA-s	CS+	2121 (1135)	926 (653)	1310 (624)	910 (589)	955 (437)
	CS-	1876 (1286)	1120 (636)	1240 (950)	943 (627)	903 (404)
A(BCD)A-s	CS+	2322 (874)	909 (490)	1457 (937)	1138(1037)	912 (607)
	CS-	2047 (1059)	1051 (655)	1588 (862)	1061 (595)	918 (491)

Note: A1 and A10 = Acquisition trials 1 and 10, respectively. E1 and E12 are Extinction trials 1 and 12 respectively.

Figure Captions

Figure 1. Mean expectancy ratings across trials in each experimental phase for the AAA-d, ABA-d and A(BCD)A-d groups which were exposed to dissimilar contexts during the extinction phase and test phase. A = acquisition phase, E = extinction and T = test. Error bars reflect the standard error of the mean.

Figure 2. Mean expectancy ratings across trials in each experimental phase for the AAA-s, ABA-s and A(BCD)A-s groups which were exposed to similar contexts during the extinction phase and test phase. A = acquisition phase, E = extinction and T = test. Error bars reflect the standard error of the mean.


4.5
4
3.5
3
2.5
2
1.5
1
0.5
Expectancy Ratings
AAA-d:
CS+
CS-
ABA-d:
CS+
CS-
A(BCD)A-d:
CS+
CS-
A1
A4
A7
A10
E1
E4
E5
E8
E9
E12
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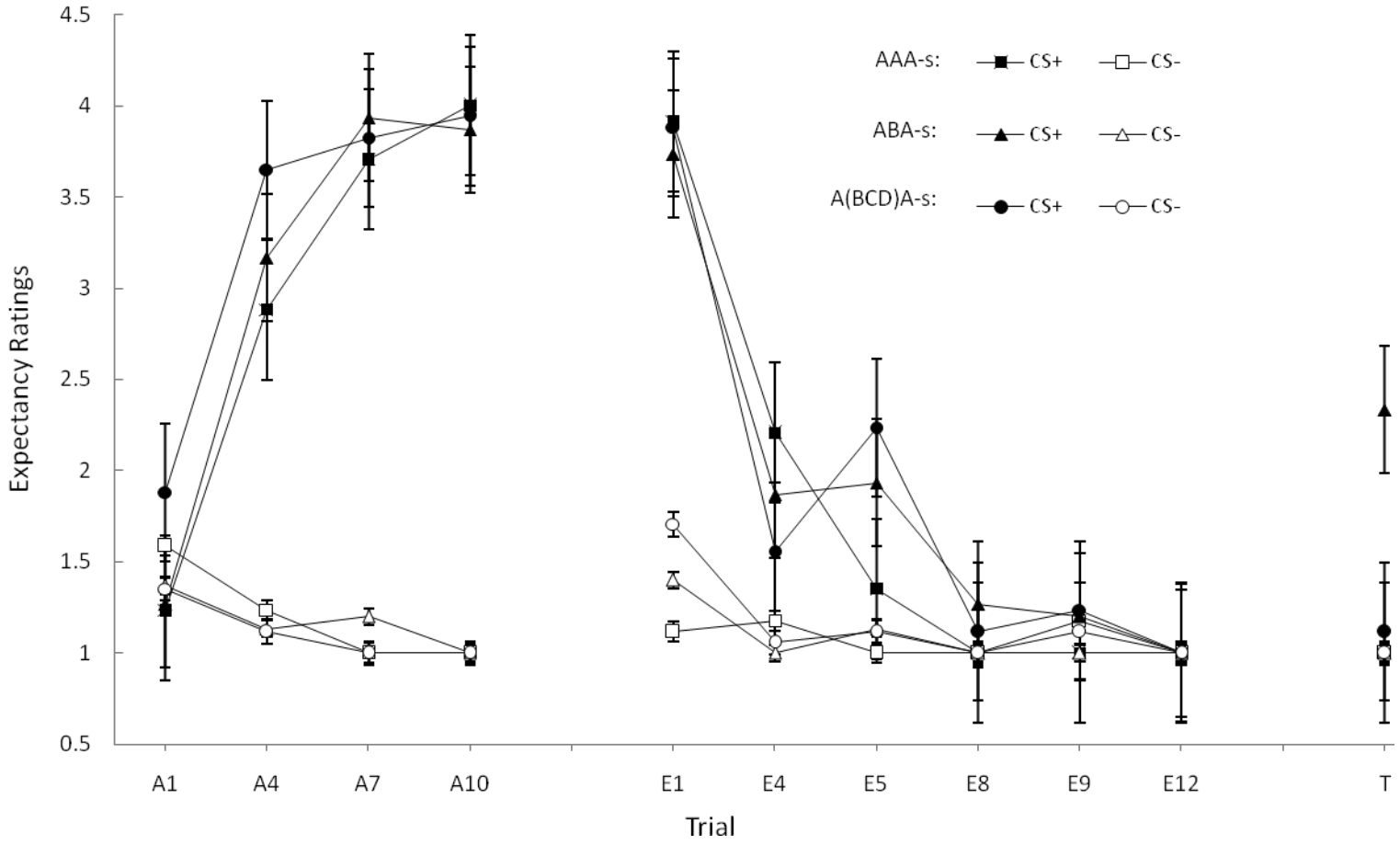
Trial


4.5
4
3.5
3
2.5
2
1.5
1
0.5
Expectancy Ratings
AAA-s: CS+ CS-
ABA-s: CS+ CS-
A(BCD)A-s: CS+ CS-
A1
A4
A7
A10
E1
E4
E5
E8
E9
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