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The effects of physical context changes and multiple extinction contexts on two forms of renewal
in a conditioned suppression task with humans

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Abstract

Three experiments examined the effects of physical context changes and multiple extinction contexts on the renewal of conditioned suppression in humans. A conditioned suppression task used an undesirable event as the unconditional stimulus (US). One conditional stimulus (CS+) predicted the occurrence of the US and another (CS-) predicted US absence. In Experiment 1 ($N = 32$), conditioned suppression was acquired to the CS+ in one context and extinguished in a different context. An increase in suppression was found for the CS+ and not for the CS- when subsequent test trials were conducted in the acquisition context (ABA renewal). Experiment 2 ($N = 32$) tested for ABC Renewal and showed increased suppression to both the CS+ and CS- when test was conducted in a novel context. Experiment 3 ($N = 80$) showed that these two effects were abolished when extinction was conducted in multiple contexts. The experiments extend the ABA renewal of conditioned suppression found with non-human animal subjects and the reduction of renewal by extinction in multiple contexts. Context changes may also facilitate cue competition effects after training with elementary stimuli, as shown by the effects of US omission in the ABA and ABC renewal groups.

Keywords: Pavlovian conditioning, extinction, context

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Pavlovian conditioning refers to the learning of the association between a conditional stimulus (CS) and an unconditional stimulus (US), such that the presentation of the CS on its own will elicit a conditional response. Wolpe (1958) proposed that anxiety disorders like phobia can be acquired through this process when a CS (e.g., spider) is paired with a fear provoking US (e.g., intense pain) to result in a conditioned fear response to the CS. Such explanations lead naturally into treatment approaches. A common treatment for anxiety disorders is based on the observation of extinction. In extinction, repeated and controlled exposure to the feared stimulus will result in a reduction of the conditioned fear response (e.g., Craske & Rowe, 1997; Öst, 1997). However, despite the reported efficacy of extinction-based treatment approaches (Chambless & Ollendick, 2001) fear may return after therapy (Rachman, 1989). A compelling case has emerged over the past two decades, largely led by the research of Bouton and colleagues (e.g., Bouton 1986; 1993; 2002; Bouton & Bolles, 1979; Bouton & Nelson, 1998), suggesting that context plays an important role in the return of conditioned behavior after extinction. By consequence, context may explain some forms of relapse following extinction-based treatment methods.

Four main phenomena that have produced a return of conditioned behavior following extinction are renewal, reinstatement, spontaneous recovery, and faster reacquisition (see Bouton, 2002; Bouton & Nelson, 1998 for reviews). Context is thought to play a role in all phenomena, although its role is most obvious with renewal. Bouton and Bolles (1979) demonstrated renewal when rats received acquisition pairings of a CS and shock US in one context followed by extinction trials of CS alone presentations in a different context.

Conditioned suppression that was lost during extinction was renewed when the CS was subsequently presented in the original learning context. This form of renewal, termed ABA renewal, is distinguished from other forms according to the nature of the contexts used in the different phases of the experiment. For instance, in ABC renewal, subjects receive acquisition CS-US pairings in one context (A), CS alone extinction trials in a second context (B), and test trials in a third context (C). Renewal of conditioned behavior is also observed in this procedure (Bouton & Bolles, 1979).

Extensive research on renewal in non-human animal subjects has established it as a relatively general phenomenon. Renewal has been found in Pavlovian conditioning preparations (e.g., Bouton & Bolles, 1979) and in operant conditioning preparations (Nakajima, Tanaka, Urushihara, & Imada, 2000; Nakajima, Urushihara, & Masaki, 2002), although most research has tended to use the former preparation. Renewal has been observed with taste aversion learning (e.g., Rosas & Bouton, 1997), fear conditioning (e.g., Bouton & King, 1983), and appetitive conditioning (e.g., Bouton & Peck, 1989) procedures. It is important for the application of renewal that it can also be observed with human subjects. Although the literature on renewal in humans is still developing, several examples have been documented (Collins & Brandon, 2002; Havermans, Keuker, Lataster, & Jansen, 2005; Mineka, Mystkowski, Hladek, & Rodriguez, 1999; Mystkowski, Craske, & Echiverri, 2002; Mystkowski, Mineka, Vernon, & Zinbarg, 2003; Rodriguez, Craske, Mineka, & Hladek, 1999; Rosas, Vila, Lugo, & López, 2001).

Previous research conducted with human subjects has largely examined ABC renewal because participants were selected on the basis of pre-existing fears or dependencies for which the context during the presumed acquisition phase is not known. Thus, the procedures did not incorporate explicit acquisition trials in the first phase of the ABC design. For instance,

Mystkowski et al. (2002) pre-selected a group of spider fearful individuals and gave them one session of graded, exposure-based treatment in a specific treatment location. Renewal of self-reported fear was observed when the individuals were exposed to a tarantula in a location that was different to that in which the treatment session was given. This renewal of spider fear also appears to occur when caffeine ingestion is used to change the internal drug state between the extinction and test phases (Mystkowski et al., 2003). In a group of selected social drinkers, Collins and Brandon (2002) found a renewal of saliva weight and urge to drink when drinkers were tested in a location different to which extinction trials of cue exposure were given.

Havermans et al. (2005) used an explicit acquisition phase in a conditioned suppression task to investigate the effects of context change on extinguished performance. The stimuli for the conditioned suppression task were presented via a computer monitor while contextual changes were defined as changes in the color of the task stimuli and/or the background color of the monitor. Evidence for ABA renewal was strongest when both the color of the task stimuli and background color of the monitor and stimuli were changed between contexts. A subsequent experiment found no evidence for ABC renewal, however. The investigators suggested that the failure to observe ABC renewal could reflect important differences in the contextual control of extinguished performance between humans and other animals. For instance, it was suggested that during acquisition, human participants learnt a rule that suppression to the conditional stimuli is only required in context A, but not in any other context. This would thus lead to a renewal of suppression when test trials are given in context A (ABA renewal) and not in a novel context (ABC renewal). In contrast, the renewal effect may be controlled by basic associative learning processes in animals, such as those described in the memory model of extinction proposed by Bouton and Nelson (1998, see also Bouton, 2002).

Bouton and Nelson (1998) have argued that the renewal of extinguished conditioned behavior is related to a context-mediated retrieval of the CS-US association. Following acquisition and extinction trials, the CS is said to have two meanings associated with the US. The first is a CS-US association and the second is a CS-noUS. This ambiguity is resolved by contextual cues that act to facilitate the appropriate association. If the context is the same as that used in extinction, the CS-noUS association is expressed in behavior, otherwise the CS-US association is expressed. In broad terms, it is the poor retrieval of the association learnt in extinction that leads to the renewal of conditioned behavior. A relapse prevention method might thus be one in which conditions are created which promote retrieval of the extinction context (Bouton, 2002) or if there is generalization from the extinction context to other contexts in which the CS is presented. The latter proposal is based on the notion that the greater the overlap in terms of shared contextual cues, the more likely the association learnt in one context will be retrieved when the organism is in another context. This idea has been tested in non-human animal research by presenting extinction trials in multiple contexts (Chelonis, Calton, Hart & Schachtman, 1999; Gunther, Denniston, & Miller, 1998). Using an ABA renewal design, Chelonis et al. (1999) gave rats lithium chloride (LiCl) contingent upon the administration of a sucrose solution. A control group did not receive extinction trials following acquisition. Another group received extinction trials in the same context as acquisition while a third group received extinction trials in a different context to acquisition, thus forming an ABA renewal group. The fourth group received extinction trials in several different contexts to that used in acquisition. All groups receive test trials of the sucrose solution in the acquisition context. Taste aversion to the sucrose solution was observed in the ABA renewal group, as expected. However, the group that received extinction trials in multiple contexts showed less taste aversion than the

ABA renewal group. A similar finding of a reduced renewal following extinction training in multiple contexts has been reported by Gunther et al. (1998) in a fear conditioning procedure with rats, although this study was based on an ABC renewal design.

The reports of a reduced renewal effect following extinction in multiple contexts in studies with rats (Chelonis et al., 1999; Gunther et al., 1998) hold promise for similar interventions with human participants. It is important that research with humans be conducted to establish the generality of these effects. Indeed, it has been argued that the extrapolation from non-human animal research to applications with humans should be based on empirically demonstrated commonalities (Branch & Hackenberg, 1998). The present research was conducted with this principle in mind. Two experiments were conducted to test for renewal of extinguished conditioned behavior in humans. A conditioned suppression task similar to that employed by Havermans et al. (2005) was used. However, context was manipulated by changing the background colors of the experimental room and by playing different background sounds. Stronger contextual manipulations may lead to a more robust ABA renewal effect (Havermans et al., 2005) and may also promote the observation of ABC renewal. A further difference to the Havermans et al. (2005) study was that a within-subjects control for associative learning effects was employed. Due to these procedural differences, it was first necessary to confirm that a renewal of conditioned behavior would be observed. Experiment 1 thus tested for renewal in an ABA renewal design. Experiment 2 tested for ABC renewal. Finally, Experiment 3 tested whether conducting extinction training in multiple contexts prior to the test phase could abolish the observed renewal effects.

EXPERIMENT 1

A common method to examine the return of conditioned behavior in animal subjects is to measure conditioned suppression (Bouton, 1984; Bouton & Bolles, 1979; Johnson, Baker, & Azorlosa, 2000; Wilson, Brooks, & Bouton, 1995). The animals are first trained through operant conditioning methods to press a bar to obtain food or water reinforcement. Acquisition trials consisting of pairings of a neutral CS and an aversive US are next given. Presentations of an aversive US (e.g., electric shock) will produce an unconditional response of suppressing the operant bar pressing. Conditioned behavior to the CS can then be measured; if the CS is presented during operant performance, suppression of bar pressing is observed. Following extinction, this suppression is reduced. Arcediano, Ortega, and Matute (1996) developed a procedure that provides a human analogue of the measurement of conditioned suppression. However, to avoid the use of an aversive US that would be strong enough to produce unconditional response suppression in humans, a US was used that became salient because of task demands. Conditioned suppression to a CS that predicts the US occurs due to anticipated punishment within the context of the task, rather than due to fear of an aversive US (Havermans et al., 2005). The task uses a computer-based format in which participants are required to destroy invading “Martians” by firing a laser gun (pressing the space bar on the computer keyboard). If the participant fires the laser gun when the Martians have deployed a “laser shield”, however, it has the consequence of allowing many Martians to invade without being destroyed. In the context of the task, the laser shield serves as the US and participants can learn to predict the occurrences of the shield US by presentations of CSs. In an acquisition phase, presentations of a CS+ are immediately followed by a shield US, whereas presentations of a CS-

are not followed by the shield US. Conditioned suppression has been shown to occur during presentations of the CS+, but not during presentations of the CS- (Arcediano et al., 1996).

The present experiment adapted the conditioned suppression task to examine ABA renewal in human participants. The ABA renewal group received acquisition trials consisting of intermixed CS+ and US pairings and CS- alone presentations in one context. Extinction trials, consisting of CS+ alone and CS- alone presentations were then given in a second context. Test trials of CS+ and CS- alone presentations, were given in the acquisition context to test for a renewal of conditioned suppression. A control group (AAA) was also employed in which acquisition, extinction, and test phases were conducted in the same context. Due to the nature of the apparatus used in the experiment, the participant completed all phases of the experiment in the same room. The environmental context was manipulated by illuminating the room with different colored lights and by playing different background sounds. It was hypothesized that conditioned suppression would develop during presentations of the CS+ in the acquisition phase, but not during presentations of the CS-. The conditioned suppression during the CS+ would be lost in the extinction phase. During the test phase, it was hypothesized that a renewal of conditioned suppression to the CS+ would be observed in the ABA renewal group. No renewal of conditioned suppression to the CS- was expected.

Method

Participants

Thirty-two first year psychology students (6 male, 26 female) from Griffith University participated in exchange for partial credit towards course requirements. The participants' ages ranged from 17 to 40 years with a mean of 22.5 years. Participants were randomly assigned to either the ABA Renewal group or the Control group upon arrival at the laboratory. Prior to

participation, all participants provided informed consent. The human research ethics committee at Griffith University approved the protocol for this and subsequent experiments.

Apparatus

Participants completed the task individually. The participant sat in a 3-m square room that had light brown sound attenuating material on the walls and a 2.4-m wide x 1.2-m high white screen in the middle of the wall at the front of the room. The door of the room was left open during the training phases, and was closed during the experiment proper. During the latter, the experiment was monitored via a closed circuit video system from an adjoining room. A Dell Latitude IBM compatible laptop computer, located in the adjoining room, was used to present the experimental stimuli and record the participant's responses. It was connected to an In Focus Lite Pro Model 730 LCD projector, which projected the images for the experimental task on to the screen in front of the participant.

The participant remained in the experimental room during all phases of the experiment, and the physical context was manipulated by a combination of visual and acoustic stimuli. The visual component of the context was presented via a panel of Crompton 60-Watt reflector spot globes mounted 2 m from the ground and directly behind the participant. The color was produced by illuminating two globes of the same color. This had the effect of illuminating the walls of the room in the selected color, either amber or blue. The acoustic component of the context was produced by playing musical digital interface (MIDI) sounds at a tempo of 85 sounds per minute. The MIDI sounds were obtained from the range of percussion instruments and were bass drum 1 (MIDI Code 36) and short whistle (MIDI Code 71). The sounds were presented by a Dell Optiplex GX1 computer that used a Crystal PnP Audio sound controller. The sound output was presented through four Altec Lansing speakers mounted 2-m from ground

level in each corner of the room. The final contexts consisted of a combination of the light and sound. Context A combined the amber light and the bass drum 1 sound, while context B combined the blue light and short whistle sound.

Procedure

The experimental task followed the procedures developed by Arcediano et al. (1996). The pretext of the task required the participant to destroy “Martians” that were attempting to invade Earth. The participant could destroy the Martians by shooting a laser gun (pressing the spacebar of the computer keyboard) as they appeared sequentially on the display. The Martian was destroyed if the participant pressed the space bar just before the Martian appeared on the screen. However, the Martians also possessed a defensive shield. Firing the laser gun when the shield was activated would allow a flood of Martians to invade. Thus, participants had to learn to suppress responding during those times in which the Martian shield was about to occur.

The Martians were represented by a cartoon style head with elongated eyes, large teeth, and no hair. A “destroyed” Martian was represented by the same head with a red X drawn over it. Martians appeared on the screen every 300 ms (in training phases) or 200 ms (during experiment proper) starting at the top left corner of the screen and forming rows of 10 Martians across the computer monitor. When eight rows filled the screen, the rows were moved up the screen and were replaced by the next row at the bottom. The CSs were simple geometric shapes that were presented upon the black background and behind the display of invading Martians. One shape was a solid white circle that subtended a visual angle of 10° , and the second shape was a white cross that subtended a visual angle of 12.1° .

The experimental task was completed in three stages. Two were training stages, and the third stage was for the experiment proper. In the first stage, participants were trained to depress

the space bar at a steady rate in order to destroy the invading Martians. The instructions used were similar to those employed by Arcediano et al. (1996).

Martians are attempting to invade Earth and it's up to you to stop them!

Martians will appear on the screen approximately every half second.

You must destroy them by shooting a laser gun just before they appear on the screen. Simply press the space bar to shoot the laser gun. If you press the space bar at just the right time, that Martian will be destroyed.

At the end of this phase, we will tell you how successful you were - what percentage of Martians you have destroyed.

THE FATE OF EARTH IS IN YOUR HANDS!

DON'T LET THE MARTIANS INVADE OUR PLANET!

Following the instructions, the 100 Martians were presented at a rate of one every 300 ms. The percentage of Martians destroyed was displayed to the participant at the conclusion of this phase.

In the second training phase, the Martian defensive shield US was introduced. Participants were told that their task was again to destroy as many Martians as possible. However, they were warned that the Martians now had a defensive shield and any shots of the laser gun during shield activation would have negative consequences.

Now the Martians have developed a powerful anti-laser shield. You must continue using your laser gun to destroy the Martians. BUT BE

CAREFUL because if you shoot your laser gun when the shield is up,
your shot will reflect back to you, and hundreds of Martians will invade.

You will not be able to stop this invasion! You will know when the
shield is up when you see an intermittent FLASHING OF THE
SCREEN.

REMEMBER: Just one shot while the shield is up (FLASHING
SCREEN) and the Martian invaders will come swarming in.

After these instructions, 160 Martians were again presented at a rate of one every 300 ms along with three presentations of the US (flashing screen) at random intervals. The flashing screen consisted of the background alternating between black and white for 1 second. The US presentations were unwarned and participants pressed the space bar during its presentation. Thus, participants were exposed to the consequence of 100 invading Martians, which filled 6 lines of the screen. The background continued to flash between black and white when the Martians invaded. The second training phase ended with the percentage of Martians destroyed being displayed.

The experiment proper began next in which the CSs were introduced. The participants were told that they may learn when to predict the shield by noticing signals that were presented.

Now there will be some SIGNALS that will help you to work out when
the shield is about to come up. But beware: there are also some false
signals. If you can figure out which signals predict the shield and which
are false then you will always be able to avoid the shield. Otherwise you

might shoot when the shield is up and the Martians will invade.

REMEMBER: Just one shot when the shield is up (FLASHING SCREEN) and the Martian invaders will come swarming in.

Following presentation of these instructions, the door of the experimental room was closed and the experimenter instigated the first context (context A). The task began with Martians presented at a rate of one every 200 ms. The CSs and US were also presented in predetermined sequences and times. The CS and US presentations were arranged into three phases: acquisition, extinction, and test. All phases ran continuously without any further instructions. The CSs were presented for 3 s on all trials during each phase. In the acquisition phase, there were 9 presentations of each CS for 3 s in duration (labeled trials A1 to A9). The CS+ was always followed immediately by a presentation of the shield US, while the CS- was always presented alone. At the end of the acquisition phase, the experimenter changed the context from A to B. The extinction phase then began with 9 presentations each of the CS+ and CS- (labeled trials E1 to E9). However, in this phase the CS+ was not followed by the shield US. At the end of the extinction phase, context A was reinstated for the test trials. The test phase consisted of three presentations each of the CS+ and CS- (labeled trials T1 to T3). As in the extinction phase, the shield US was not presented. The order of the CS+ and CS- presentations were randomized with the restriction that no more than three presentations of the same type of CS could be made in succession and the first two stimuli presented in the test phase were a CS+ and CS-. In addition, the nature of which shape served as the CS+ and CS- (circle or cross) and the nature of which CS was presented first in the acquisition, extinction, and test

phases was fully counterbalanced to result in 16 unique trial sequences. The intertrial interval randomly varied from 5 to 10 s with a mean of 7.5 s CS offset to CS onset.

The dependent variable of suppression ratio was calculated through the formula $X/(X+Y)$. In this formula, X represents the number of spacebar presses during the 3 s duration of the CS presentation and Y is the number of spacebar presses in the 3 s immediately prior to the CS onset. A ratio of 0 is indicative of absolute response suppression during the CS, while a ratio of .5 would reflect no suppression.

Results and Discussion

The mean conditioned suppression across the experiment is shown in Figure 1 for the Control group (top panel) and ABA Renewal group (bottom panel). The two groups showed a similar pattern during the acquisition and extinction phases, but differed in the test phase. The data was examined with ANOVAs that used Greenhouse-Geisser adjusted degrees of freedom for all main effects and interactions involving more than two levels to correct for violations of the sphericity assumption. The F ratios are reported with the unadjusted degrees of freedom and the ϵ used in the correction. A $2 \times 2 \times 9$ (Group $\times$ CS $\times$ Trial) mixed factorial ANOVA for the acquisition phase confirmed that both groups showed the development of conditioned suppression during the CS+ and a loss of suppression during the CS-. The analyses yielded a main effect for CS, $F(1, 30) = 49.77, p < .001$, and a CS $\times$ Trial interaction, $F(8, 240) = 4.02, \epsilon = .48, p < .01$. All other F s < 2.19 . In the extinction phase, conditioned suppression during the CS+ was lost, such that there was no difference in response suppression between the CS+ and CS- on the last extinction trial. A $2 \times 2 \times 9$ (Group $\times$ CS $\times$ Trial) mixed factorial ANOVA yielded a main effect for CS, $F(1, 30) = 22.30, p < .001$, main effect for Trial, $F(8, 240) =$

11.71, $\varepsilon = .41$, $p < .001$, and a CS x Trial interaction, $F(8, 240) = 13.21$, $\varepsilon = .42$, $p < .001$. All other F s < 1.74 .

 Insert Figure 1 about here

In the test phase, conditioned suppression did not appear to differ between the CS+ and CS- for the Control group, but did differ in the ABA renewal group. A 2 x 2 x 3 (Group x CS x Trial) ANOVA yielded a main effect for CS, $F(1, 30) = 5.67$, $p < .05$, a CS x Group interaction, $F(1, 30) = 4.41$, $p < .05$, main effect for Trial, $F(2, 60) = 5.19$, $\varepsilon = .98$, $p < .01$, a Trial x Group interaction, $F(2, 60) = 3.75$, $\varepsilon = .98$, $p < .05$, and a CS x Trial x Group interaction, $F(2, 60) = 4.49$, $\varepsilon = .81$, $p < .05$. The three-way interaction was examined with t tests that were adjusted for the accumulation of Type I error by using Šidák's multiplicative inequality (Games, 1977). Suppression was significantly greater during the CS+ than during the CS- on Trials 1 and 3, both $t > 5.27$, $p < .01$, but not Trial 2, $t < 1$, $p > .05$, for the ABA Renewal group. There were no differences between the CS+ and CS- on any trial for the Control group, all $t < 1$, $p > .05$. These comparisons thus confirm that renewal of conditioned suppression was observed in the ABA renewal group and this effect appeared to be strongest on the first test trial.

To further examine the extent of renewal that was observed, a comparison between the last extinction trial and the first test trial was made with a 2 x 2 x 2 (Group x CS x Trial) ANOVA. The analyses resulted in a main effect for CS, $F(1, 30) = 5.18$, $p < .05$, a Group x Trial interaction, $F(1, 30) = 7.49$, $p < .05$, and a CS x Trial x Group interaction, $F(1, 30) = 8.82$, $p < .01$. Examination of the interaction showed that suppression during the CS+ was greater on the first test trial than on the last extinction trial for the ABA Renewal group, $t(30) = 4.86$, $p < .01$.

.01. No other comparisons reached statistical significance, all $t_s < 1.66$, $p > .05$. This analysis confirms that conditioned suppression was renewed on the first test trial relative to the last extinction trial, and that this renewal was specific to the CS+ in the ABA Renewal group.

The present findings are consistent with the outcomes reported by Rosas et al. (2001) in which a form of ABA renewal was observed in a contingency learning task based on a fictitious scenario and Havermans et al. (2005) in which ABA renewal was observed in the conditioned suppression task used here. The present experiment is different, however, in that the context was manipulated by changing the background lighting and sounds in the participant's environment, rather than using different locations (hospitals) within a fictitious scenario (Rosas et al., 2001) or changes in the color of the task stimuli and background color on the computer monitor (Havermans et al., 2005). It may be argued that the present contextual manipulations present enhanced real-world validity and are more similar to the environmental contextual manipulations used in animal research (e.g., Bouton & Bolles, 1979). The present experiment also differed from Havermans et al. (2005) in that a within-subjects control for conditioning and renewal was employed. There was no evidence that contextual changes influenced responses to the CS-, a CS that was never paired with the US. The present findings and those of prior research (Havermans et al., 2005; Rosas et al., 2001) complement each other by increasing the generality of the ABA renewal effects across different experimental procedures and context manipulations. Experiment 2 aimed to extend these findings by testing for ABC renewal.

EXPERIMENT 2

The methods of Experiment 2 were similar to those used for the previous experiment except that an ABC renewal design was employed. Using physical context manipulations, participants in an ABC Renewal group received acquisition trials of CS+ and US pairings and

CS- alone presentations in one context, extinction trials of CS+ alone and CS- alone presentations in a second context, and test trials of CS+ and CS- alone presentations in a third, novel context. A control group received all phases of the experiment in the same context. It was hypothesized that the findings would support the conclusions of Experiment 1 in that a renewal of conditioned suppression would be observed in the ABC renewal group. Like the findings of Experiment 1, it was hypothesized that a renewal of response suppression in the test phase would be found for the CS+, and not for the CS-, because only the CS+ had been previously associated with the US in the acquisition phase.

Method

Participants

The participants were 29 female and 4 male psychology students who did not participate in Experiment 1. One male participant was excluded due to a failure to comply with task instructions. The participants' mean age was 21.8 years (range 18 to 52 years). After providing consent, each participant was randomly allocated to either the Control or ABC Renewal group.

Apparatus and Procedure

The apparatus replicated that used for Experiment 1 with the exception of the stimuli used as the contexts. As in Experiment 1, a combination of two colored spot globes and background sounds were used. In the present experiment, context A combined a blue light and short whistle sound (MIDI Code 71), context B combined a red light and acoustic snare sound (MIDI Code 38), and context C combined a green light and low bongo sound (MIDI Code 61).

The procedure followed that used for Experiment 1, except that the shapes used as the CS+ and CS- were changed, the number and duration of the CS presentations were varied, and the renewal group received test trials in a novel context. The CS+ and CS- consisted of outlines

of a circle and square. In the experiment proper, the three phases were again acquisition, extinction, and test. However, the number of trials in the acquisition and extinction phases were increased, and the duration of the CSs was varied. The latter manipulation was intended to make the duration of the CS less predictable to the participant (see Arcediano et al., 1996). The acquisition phase consisted of 17 presentations each of the CS+ and CS-. The CSs were presented for 3 s on Trials 1, 5, 9, 13, and 17 (labeled trials A1, A5, A9, A13, and A17). The CSs were presented for 1 s for the remaining trials. The extinction phase consisted of 21 presentations of each CS, such that the CSs were presented for 3 s on Trials 1, 5, 9, 13, 17, and 21 (labeled trials E1, E5, E9, E13, and E21), and for 1 s on the remaining trials. The test phase consisted of 3 presentations of each CS, with the CS presented for 3 s on all trials (labeled trials T1, T2, and T3). The procedure for the Control group followed that used for Experiment 1 in that context A was instigated at the start of the experiment proper and did not change through all phases. For the ABC Renewal group, context A was initiated prior to the acquisition trials, a change to context B was made between the acquisition and extinction trials, and a change to context C was made between the extinction and test trials.

Results and Discussion

Following the methods of Arcediano et al. (1996), only the 3-s presentations of each CS were examined for learning effects to provide more stable data. The mean conditioned suppression ratio in the Control group (top panel) and ABC Renewal group (bottom panel) can be seen in Figure 2. The development of conditioned suppression during the CS+ and its loss during the CS- was confirmed through a 2 x 2 x 5 (Group x CS x Trial) ANOVA by a main effect for CS, $F(1, 30) = 361.87, p < .001$, main effect for Trial, $F(4, 120) = 5.62, \varepsilon = .41, p < .05$, and a CS x Trial interaction, $F(4, 120) = 55.78, \varepsilon = .59, p < .001$. All other F s $< 3.59, p >$

.05. In the extinction phase, both groups showed a change in conditioned suppression to the CS+ and little change in suppression to the CS- across trials. The change in conditioned suppression to the CS+ was most pronounced in the ABC Renewal group. A $2 \times 2 \times 6$ (Group x CS x Trial) ANOVA yielded a main effect for Trial, $F(5, 150) = 104.55$, $\epsilon = .44$, $p < .001$, and a CS x Trial interaction, $F(5, 150) = 73.38$, $\epsilon = .48$, $p < .001$. The interaction showed that while suppression was greater during the CS+ than during the CS- on extinction trials E1 and E5, both $t(150) > 3.56$, $p < .01$, the differences between the CSs were not significant on any subsequent extinction trials, all $t(150) < 2.32$, $p < .05$, thus confirming the extinction of conditioned suppression. The differences between groups were reflected in a main effect for Group, $F(1, 30) = 7.49$, $p < .05$, and a Group x CS interaction, $F(1, 30) = 9.92$, $p < .01$. Comparisons showed that suppression of responding during the CS+ was significantly greater in the Control group than in the ABC Renewal group, $t(30) = 4.26$, $p < .01$, whereas there was no difference between the groups for the CS-, $t < 1$. All other main effects and interactions from the ANOVA were not significant, all other F s < 2.13 , $p > .05$.

 Insert Figure 2 about here

In the test phase, there was little change in conditioned suppression across trials during either the CS+ or CS- for the Control group. In contrast, suppression of responding appeared to be more pronounced on the first test trial for both the CS+ and CS- in comparison to subsequent test trials for the ABC Renewal group. A $2 \times 2 \times 3$ (Group x CS x Trial) ANOVA conducted on the three test trials resulted in a main effect for CS, $F(1, 30) = 5.06$, $p < .05$, a main effect for Trial, $F(2, 60) = 5.37$, $\epsilon = .78$, $p < .05$, a Group x CS interaction, $F(1, 30) = 6.75$, $p < .05$, and a

Group x Trial interaction, $F(2, 60) = 4.65$, $\epsilon = .78$, $p < .05$. All other F s < 2.61 , $p > .05$. The Group x CS interaction reflected greater suppression during the CS+ than during the CS- in the Control group, $t(30) = 3.43$, $p < .01$, whereas there was no difference between the CS+ and CS- in the ABC Renewal group. It would appear that this interaction reflects the continuation of some conditioned suppression to the CS+ that remained at the end of the extinction phase in the Control group. The Group x Trial interaction was due to greater suppression of responding to the CSs on the first test trial than on the third test trial in the ABC renewal group, $t(60) = 3.47$, $p < .01$, whereas all other comparisons failed to reach significance, all t s < 2.63 , $p > .05$. In sum, the analyses suggest that there was little change in conditioned suppression to any CS across the test trials in the Control group. In the ABC Renewal group, conditioned suppression to the CS+ and CS- did not differ but was overall greater on the first test trial than on subsequent trials.

The statistical analyses that compared the last extinction trial and the first test trial with a $2 \times 2 \times 2$ (Group x CS x Trial) ANOVA yielded a main effect for Trial, $F(1, 30) = 5.17$, $p < .05$, a Group x Trial interaction, $F(1, 30) = 5.35$, $p < .05$, and a Group x CS interaction, $F(1, 30) = 6.83$, $p < .05$. The Group x CS interaction again reflected that suppression was greater during the CS+ than during the CS- in the Control group, $t(30) = 2.40$, $p < .05$, whereas there was no difference between CSs for the ABC Renewal group, $t < 1$. The Group x Trial interaction showed that conditioned suppression was greater on the first test trial than on the last extinction trial in the ABC Renewal group, $t(30) = 3.05$, $p < .05$. There was no difference between the extinction and test trials for the Control group, $t < 1$. This finding of greater suppression during the first test trial than the last extinction trial in the ABC Renewal group is unusual in that the renewal of suppression was present for both the CS+ and CS-. The CS- was not paired with the US in the acquisition phase and no conditioned suppression developed during this CS. If

conditioned suppression did not develop to the CS- in first place, it is difficult to argue that conditioned suppression to the CS- was “renewed” following extinction. This is in contrast to the CS+ in which strong conditioned suppression was evidenced during the acquisition phase. These findings contrast to Experiment 1, in which an ABA renewal design was used. In Experiment 1, an increase in conditioned suppression to the CS+, but not to the CS-, was observed during test. It may be premature at this time to make any further interpretation of these findings until its reliability can be determined. Experiment 3, therefore, replicated both the ABA and ABC renewal designs of Experiments 1 and 2, respectively, and investigated the hypothesis that conducting extinction in multiple contexts would abolish renewal.

EXPERIMENT 3

Experiment 3 aimed to replicate and extend the conclusions of the previous two experiments. The procedure incorporated groups based on the ABA and ABC renewal designs used in the previous experiments. In addition, the effects of conducting extinction trials in multiple extinction contexts on conditioned suppression during the test trials was examined. The ABA Multiple Extinction Context Renewal group was based on the ABA Renewal design, and the ABC Multiple Extinction Context Renewal group was based on the ABC Renewal design. The number of extinction trials were held constant in all groups; thus although the multiple extinction context groups received extinction trials in three different contexts, participants in these groups did not receive any more extinction trials than the other groups. A fifth group served as a control in which acquisition trials, extinction trials, and test trials were conducted in the same context. It was hypothesized that the findings of Experiment 1 and 2 would be replicated. The renewal of conditioned suppression to the CS+ was expected to be found for the ABA Renewal group. A renewal of conditioned suppression was also expected for the ABC

Renewal group, although increased conditioned suppression was expected for both the CS+ and CS-. Based on the findings of Chelonis et al. (1999) and Gunther et al. (1998), in which multiple extinction contexts attenuated the renewal of conditioned behavior in animal subjects, it was hypothesized that no renewal of conditioned suppression would be observed in either the ABA or ABC Multiple Extinction Context Renewal groups.

Method

Participants

The participants were 60 female and 26 male psychology students (mean age of 23.97, range 17 to 47 years) who did not participate in Experiments 1 or 2. Three participants were excluded for failing to comply with the task instructions, one participant due to computer error, and two due to experimenter error. After providing consent, each participant was randomly allocated to one of five groups such that each group had the same number of males and females.

Apparatus and Procedure

The methods followed those used in Experiment 1 and 2 with the exception of some different apparatus used, additional contexts, and the employment of additional groups of participants. The computer that controlled the experimental task and collected the behavioral responses was a Dell Optiplex GX270 computer installed with a SoundMAX Integrated Digital Audio device with MIDI playback via a GS Wavetable SW Synthesizer. The computer was interfaced with a Panasonic PT-L777E LCD projector to display task stimuli. The context manipulations combined a color produced by two light globes positioned behind the participant with a sound produced by playing a MIDI sound at 60 beats per minute. Context A combined an amber light with a base drum sound (MIDI Code 36), context B combined a blue light with a short whistle sound (MIDI Code 71), context C combined purple lights with a hand clap sound

(MIDI Code 39), context D combined green lights with a claves sound (MIDI Code 75), and context E combined red lights with a high timbale sound (MIDI Code 65).

The number and sequencing of trials and the instructions for all phases of the experiment replicated those used in Experiment 2. In the Control group, context A was implemented prior to the acquisition phase and did not change during any phase of the experiment. In the ABA Renewal group, context A was implemented prior to the acquisition phase, changed to context B between the acquisition and extinction phases, and returned to context A between the extinction and test phases. In the ABA Multiple Extinction Context Renewal group, context A was implemented prior to the acquisition phase. During the extinction phase, the context was changed such that there was a change to context B prior to trial E1, a change to context D prior to trial E8, and a change to context E prior to trial E15. The context was changed to context A between the extinction and test phases. In the ABC renewal group, acquisition trials were conducted in context A, extinction trials in context B, but test trials were conducted in context C. In the ABC Multiple Extinction Context Renewal group, acquisition trials were conducted in context A, extinction trials E1 to E7 in context B, extinction trials E8 to E14 in context D, extinction trials E15 to E21 in context E, and all test trials in context C. In sum, all groups received the same number of extinction trials prior to the test trials. The ABA renewal groups always received test trials in the same context as used in acquisition (context A), whereas the ABC renewal groups always received test trials in a novel context (context C). The ABA and ABC renewal groups received extinction trials in only one context (context B). The ABA and ABC multiple extinction context groups received extinction trials that were distributed evenly across three contexts (contexts B, D, and E) prior to the test trials.

Results and Discussion

As in the previous experiments, suppression ratios were calculated only for the 3-s CS presentations. The mean suppression ratio during the three phases of the experiment are shown in Figure 3, for the comparisons between the Control group and the two ABA renewal groups, and in Figure 4, for the comparisons between the Control group and the two ABC renewal groups. Similar to the previous experiments, suppression of responding developed to the CS+ and was lost to the CS- in all groups during the acquisition phase. The acquisition of conditioned suppression to the CS+ was supported through a 5 x 2 x 5 (Group x CS x Trial) ANOVA by a main effect for CS, $F(1, 75) = 599.09, p < .001$, a main effect for Trial, $F(4, 16) = 16.78, \epsilon = .60, p < .001$, and a CS x Trial interaction, $F(4, 300) = 176.59, \epsilon = .51, p < .001$. A Group x CS interaction, $F(4, 75) = 2.71, p < .05$, was also found and indicated that there was less suppression of responding during the CS+ in the ABC Multiple Extinction Context group than in the ABA Renewal group and the Control group, both $ts > 3.15, p < .05$. All other main effects and interactions were not significant, all $F_s < 1.69$.

 Insert Figures 3 and 4 about here

In the extinction phase, all groups showed a pattern of reduced suppression of responding during the CS+, such that there was a similar level of conditioned suppression during the CS+ and CS- on the last extinction trial. The statistical analyses for the extinction phase used a 5 x 2 x 6 (Group x CS x Trial) ANOVA and yielded a main effect for CS, $F(1, 75) = 76.73, p < .001$, main effect for Trial, $F(5, 375) = 163.60, \epsilon = .29, p < .001$, and a CS x Trial interaction, $F(5, 375) = 49.31, \epsilon = .34, p < .001$, confirming that there was extinction of conditioned suppression.

The groups differed across the extinction trials as shown by a Group x CS interaction, $F(4, 75) = 6.39, p < .001$, and a Group x CS x Trial interaction, $F(20, 375) = 3.90, \epsilon = .34, p < .01$. The three-way interaction was examined further by making comparisons between the successive extinction trials (e.g., E1 vs. E5, E5 vs. E9, E9 vs. E13 etc.) separately for each Group and CS. For all groups, suppression of responding during the CS+ was greater on extinction trial E1 than on trial E5, all $t_s > 4.96, p < .05$, whereas there were no differences between trial E5 and trial E9 or any subsequent successive trials, all $t_s < 1.39, p > .05$. The pattern in response suppression during the CS- across trials differed between the groups. In the ABA Renewal and ABC Renewal groups, response suppression was greater on trial E1 than on trial E5, both $t_s > 3.60, p < .05$, but there were no differences between any subsequent successive trials, all $t_s < 1$. In the ABA Multiple Extinction Context Renewal and the ABC Multiple Extinction Context Renewal groups, the difference between trials E1 and E5 did not reach significance when protected tests were used, both $t_s < 2.27, p > .05$. In the Control group, there were no differences across successive trials for the CS-, all $t_s < 1$. In sum, it appears that there was an initial increase in conditioned suppression to the CS- for all the renewal groups, but not for the control groups. As a result, the suppression of responding to the CS- remained relatively constant across all extinction trials in the Control group, but decreased across trials in the renewal groups. This difference between groups suggests that the context change immediately before the first extinction trial influenced responses during the CS-. Nevertheless, all groups showed complete extinction of conditioned suppression, as shown by no difference between the CS+ and CS- on the last extinction trial.

The groups differed in the pattern of conditioned suppression during the test phase as confirmed with a $5 \times 2 \times 3$ (Group x CS x Trial) ANOVA conducted for the three test trials. The

analyses yielded a main effect for Group, $F(4, 75) = 12.59, p < .001$, a main effect for Trial, $F(2, 150) = 33.53, \epsilon = .52, p < .001$, a Group x Trial interaction, $F(8, 150) = 11.58, \epsilon = .55, p < .001$, Group x CS interaction, $F(4, 75) = 6.12, p < .05$, and a Group x CS x Trial interaction, $F(8, 150) = 4.91, \epsilon = .55, p < .001$. All other main effects and interactions were not significant, all $F_s < 1.95, p > .05$. Subsequent comparisons revealed that suppression of responding was greater during the CS+ than during the CS- on the first test trial in the ABA Renewal group, $t(150) = 5.37, p < .01$. The comparison between the CS+ and CS- on the first test trial for the ABC Renewal group did not reach significance, all $t_s < 2.37, p > .05$. All comparisons between the CS+ and CS- for the Control group and the ABA and ABC Multiple Extinction Context groups were not significant, all $t_s < 1$. In sum, renewal of conditioned suppression, when defined as an increase in suppression during the CS+ relative to the CS-, was observed for the ABA renewal group, but not in the remaining groups.

The statistical analyses that compared the last extinction trial and the first test trial with a 5 x 2 x 2 (Group x CS x Trial) ANOVA yielded a main effect for Group, $F(1, 75) = 11.59, p < .001$, a main effect for Trial, $F(1, 75) = 35.73, p < .001$, a Group x Trial interaction, $F(4, 75) = 12.71, p < .001$, a Group x CS interaction, $F(4, 75) = 5.64, p < .01$, and a Group x CS x Trial interaction, $F(4, 75) = 5.17, p < .01$. The pairwise comparisons showed that suppression of responding was greater on the first test trial than on the last extinction trial for the CS+, $t(75) = 11.14, p < .01$, and CS-, $t(75) = 4.68, p < .01$, in the ABA Renewal group. Likewise, conditioned suppression was greater on the first test trial than on the last extinction trial for the CS+, $t(75) = 5.95, p < .01$, and CS-, $t(75) = 9.18, p < .01$, in the ABC Renewal group. There were no differences between the trials for either the CS+ or CS- in the Control group or the ABA and ABC Multiple Extinction Context groups. These analyses, in conjunction with the

conditioned suppression observed across the three test trials, indicates a complex but consistent pattern. Renewal of conditioned suppression to the CS+ and CS- was found for both the ABA Renewal and ABC Renewal groups. However, the renewal of suppression was significantly greater for the CS+ than for the CS- only in the ABA Renewal group. Both these effects were abolished by conducting extinction trials in multiple contexts, as shown by no differences between the CS+ and CS- during test trials and no differences between the last extinction trial and first test trial in the ABA and ABC Multiple Extinction Context groups. The present findings confirm previous experiments conducted with non-human animal subjects in which there was an abolishment of renewal effects following multiple extinction treatments in both an ABA renewal design (Chelonis et al., 1999) and an ABC renewal design (Gunther et al., 1998).

The unexpected finding of increased suppression to the CS- on the test trials that was observed for the ABC Renewal group in Experiment 2 was replicated. Moreover, an increase in response suppression to the CS- on the first test trial was also observed in the ABA Renewal group. This latter finding contrasts with the those observed in Experiment 1. The present experiment differed from Experiment 1 in that there were a larger number of extinction trials and that the presentations of the CSs were varied between 1 s and 3 s. It is not clear whether either of these differences can account for the contradictory findings. The finding of increased response suppression during the CS-, a CS that was used as a control stimulus because it was not paired with the US and should thus have little or no association with the US, may have important implications for our understanding of the effects of contextual changes on extinguished conditioned behavior in humans.

General Discussion

The present experiments had two aims. First, to test for ABA renewal and ABC renewal effects in human participants by using a conditioned suppression task. Experiment 1 demonstrated ABA renewal. Experiment 2 tested for ABC renewal and showed an increase in suppression to an extinguished excitatory CS (CS+). However, an increase in suppression was also observed for the control CS (CS-). Second, to test the hypothesis that conducting extinction treatment in multiple contexts would abolish the renewal of conditioned suppression observed in the ABA and ABC renewal procedures. This hypothesis was confirmed in Experiment 3. The present experiments extend the generality of the ABA renewal effect to human participants in a conditioned suppression task and suggests that renewed conditioned suppression can be reduced by experimental manipulations that are conducted during the extinction phase. In the context of clinical practice, the present findings suggest that conducting an extinction-based treatment technique, such as exposure therapy, in multiple contexts may reduce relapse that is caused by a renewal type effect.

The demonstration of ABA renewal suggests that the conditioned suppression task used in the present experiments holds promise for future research on renewal in human participants. The present task allows for the same measure of conditioned behavior to be examined in both human and non-human animal subjects. As argued by Arecediano et al. (1996), this parallel provides a direct and possibly more ecologically valid way to compare the two areas of research. The present use of physical contextual manipulations in the participants environment, rather than changes in the colors of the task stimuli and the background of the computer screen (e.g., Havermans et al., 2001) also enhances the parallels between research using humans and other animals. The present task design also complements research that has used human participants

pre-selected on the basis of existing fears or dependencies for which there is no experimental acquisition phase (Mineka et al., 1999; Mystkowski, et al., 2002, 2003; Rodriguez et al., 1999). Because the present task includes an explicit acquisition phase of CS and US pairings, the effects of experimental manipulations during acquisition can be investigated (e.g., Gunther et al., 1998). Moreover, the investigation of renewal with human participants allows for potentially important cognitive variables, such as the use of verbal memory prompts or type of instructions, to be investigated. This is important because the development of fears and anxieties in humans is often more complex than the simple Pavlovian conditioning model proposes as they may, for instance, develop from vicarious learning or instructions (e.g., Ollendick & King, 1991). The influence of such factors on renewal in humans requires further investigation.

An intriguing difference in the renewal effects between the ABA Renewal group and the ABC Renewal group emerged. Suppression of responding during the first test trial was significantly greater during the CS+ than during the CS- in the ABA Renewal group, whereas there was no difference between the CSs in the ABC Renewal group. However, in the ABC Renewal group, suppression of responding during the CS+ and CS- was greater on the first test trial than on the last extinction trial. Supplementary *post hoc* analyses conducted on the ABA Renewal and ABC Renewal groups in Experiment 3 showed that the suppression of responding during the CS+ was significantly greater in the ABA Renewal group than in the ABC Renewal group, $t(30) = 4.14, p < .001$. This outcome is consistent with the frequently cited observation that ABA renewal is stronger than ABC renewal (e.g., Harris et al., 2000). However, suppression of responding during the CS- was significantly greater in the ABC Renewal group than in the ABA Renewal group, $t(30) = 3.59, p < .001$. This increased suppression of responding during the CS- is unexpected because this CS was never paired with the US. If it

were not for the increased suppression to the CS- on test, one might have concluded that the ABC renewal effect has been demonstrated. Havermans et al. (2005) suggested that the lack of a clear ABC renewal effect in their experiment might be due to the extinction context B acquiring a direct inhibitory association with the US during extinction. However, they provided a test that ruled out this explanation. By extension, it would be unlikely to account for the present findings.

Havermans et al. (2005) proposed that they observed a clear ABA renewal effect but not an ABC renewal effect because of a generalization decrement following the contextual changes. In the context of the present task, this would suggest that a configural context-CS+ stimulus was formed and associated with the US during acquisition. The change in context for the test trials in the ABC renewal group influenced suppression to the CS+ because the novel context resulted in a decrement in generalization from the acquisition context. In contrast, the ABA renewal group received the reinstated configural context-CS+ stimulus during the test phase. This generalization decrement for the ABC renewal group would explain why conditioned suppression to the CS+ was greater for the ABA Renewal group than in the ABC Renewal group. However, conditioned suppression was still evident for the CS+ in the ABC Renewal group as shown by greater suppression on the first test trial than on the last extinction trial. A generalization decrement may thus not fully account for the present pattern of results for the CS+. The mechanism of a generalization decrement can provide an explanation for the increased suppression to the CS- in the ABC Renewal group. During acquisition a configural context-CS- stimulus was associated with noUS. Upon testing in the novel context, only part of this configural cue, and hence the inhibitory noUS association, was reinstated since the context was now novel, leading to increased suppression to the CS- during test.

Havermans et al. (2005) offered a further possible explanation for the observation of ABA renewal and not ABC renewal in their experiments. It was suggested that ABC renewal may not be found with humans if participants adopt a rule based approach to the learning task in which a rule states that suppression is only required in the acquisition context. While this rule as currently given may not fully explain the increased suppression for both the CS+ and CS- in the ABC renewal group and the difference between the ABA and ABC renewal groups for the CS- in the test phase, it does highlight the potential importance of rule learning in associative learning tasks with human participants. A rule based explanation for the present pattern of results would have to take into account the effects of context. Two pieces of evidence support this claim. First, suppression of responding during the CS- occurred on the first test trial, which followed a change from the extinction context to the test context. Second, as can be seen in Figures 3 and 4, and was confirmed by the statistical analyses, suppression of responding to the CS- was apparent during the first extinction trial in all the renewal groups. All these groups received a context change between acquisition and extinction. In contrast, the Control group, in which there was no context change, did not show any increase in suppression of responding on the first extinction trial. The increased suppression to the CS- seems to reflect a more general phenomenon as it is not specific to the test phase in a renewal design. The novelty of the context appears to play an additional role in that the suppression to the CS- was greater in the ABC Renewal group than in the ABA Renewal group in the test phase. In the latter group, the test phase was not novel because it was the same as that used in the acquisition phase.

The finding of increased suppression to the CS- following a change of context is perplexing because the meaning of this stimulus did not change throughout the experiment. The CS- had only one meaning associated with it in that it was not predictive of the US, and it may

be termed a “safety signal”. As argued by Bouton (1993, 2002; Bouton & Nelson, 1998), when a stimulus has a single meaning associated with it, the stimulus is not ambiguous, and there is no need for context to be used to disambiguate it. In these cases, it is thought that the meaning of the stimulus is stored independently of context. There is experimental evidence to support this notion. For instance, there is little change in excitatory conditioned behavior when the context is changed after acquisition training (e.g., Bouton & King, 1983; Bouton & Peck, 1989; Harris, Jones, Bailey, & Westbrook, 2000). It also not likely to be related to the uniqueness of the CS- as a safety signal since conditioned inhibition also generalizes across contexts (Bouton & Nelson, 1994). If the meaning of the CS- did not change during the experiment, the increased suppression to the CS- following a change of context might reflect the effects of a stimulus for which the meaning did change – the CS+.

The present experiment used full counterbalancing of which CS was presented first in each phase. In addition, up to the first extinction trial, all the renewal groups were treated in an identical manner. This provides a means to investigate the results in more detail. All four renewal groups can be split into two broad groups, those that received the CS+ on the first extinction trial and those that received the CS- on the first extinction trial ($n = 32$ in each). Note that the first extinction trial occurred after the context was changed from the acquisition context to the extinction context, and this context was novel. The first presentation of the CS+ in the extinction phase was not followed by the US, an outcome that was unexpected for the participants. Suppression of responding during the CS- for participants who received the CS+ alone presentation first in extinction ($M = .34$, $SD = .14$) was greater than for participants who received the CS- alone presentation first in extinction ($M = .45$, $SD = .10$), $t(62) = 3.33$, $p < .01$. This suggests that it was not only a change of context that disrupted behavior to the CS-, but also

new information learnt about the CS+. This conclusion is reinforced by the lack of a significant difference in response suppression to the CS+ between participants who received the CS+ first and those that received the CS- first in extinction, $t(62) = 1.24, p > .05$. New learning that the CS+ is no longer followed by the US appears to have influenced the participant's responses during the CS- when it was presented on the next extinction trial.

A similar examination can be extended to the test phase since the nature of the first stimulus presented in this phase was also counterbalanced. These comparisons are described only for the ABA Renewal and ABC Renewal groups used in Experiment 3, although the same pattern of results were observed in the previous experiments. In the ABA Renewal group, there was no significant difference between groups for either the CS+ or CS- when groups were formed on the basis of whether the CS+ or CS- was presented first in test. Because the test context was the same as that for the acquisition trials, there was no new context-dependent learning for these participants. In the ABC Renewal group, there was no effect of whether the CS+ was the first stimulus presented or the CS- was the first stimulus presented in the test phase in response suppression to the CS+. However, response suppression to the CS- was significantly greater for participants that were presented with the CS+ first in test ($M = .24, SD = .12$) than for participants that were presented with the CS- first in test ($M = .45, SD = .09$), $t(14) = 4.01, p < .01$. This replicates the pattern found for the first extinction trial and suggests that responding to the CS- was influenced by prior learning about the CS+ in a novel context.

The effects of the omission of expected US presentations on elementary and compound trained stimuli has received attention in prior research with humans (e.g., Lipp & Dal Santo, 2002; Matute & Pineño, 1998; Ortega & Matute, 2000; Pineño & Matute, 2000). Indeed, Lipp and Dal Santo (2002, Experiment 4) used the same conditioned suppression task as used in the

present research and presented acquisition trials of CS+ and US pairings and CS- alone presentations. Following acquisition, the CS+ was again presented, but was not followed by the US. The effects of this treatment trial, which Lipp and Dal Santo (2002) termed US omission, on responding to the CS- was investigated in their experiment. As such, the experimental procedure replicates very closely the methods used in the present research when the first two extinction trials are examined for those participants that received the CS+ alone on the first extinction trial. Unlike the present research, Lipp and Dal Santo (2002) did not find any suppression of responding to the CS- when it was presented after the CS+ alone trial (Lipp & Dal Santo, 2002, Experiment 5). The major difference between the present experiment and that reported by Lipp and Dal Santo (2002) was that the present research incorporated a context change between the acquisition and extinction (US omission) trials. It may be that the effect of US omission requires that a context change is implemented. The fact that there was no effect of US omission on the first extinction trial in the Control group in any experiment reported here supports this interpretation.

Havermans et al. (2005) highlighted the impact of rule learning on the pattern of suppression observed in an ABA and ABC renewal procedure. The effects of US omission observed in the present experiment may also reflect rule learning. Participants may have adopted a rule such as “one of the two CSs is followed by the US, and this is the CS+”. Following the first extinction or test trial in which the CS+ was presented alone, participants might have thought that the contingencies had now reversed, with reasoning such as “since the CS+ is no longer followed by the US in this new context, then the CS- will now be”. This reversal would have maintained consistency with the general rule that “one of the CSs is followed by the US”. Moreover, if such a rule was being adopted, it must have incorporated a rule about the context

because there was no significant change in suppression during the CS- between the extinction and test phases in the Control group. Lipp and Dal Santo (2002) explicitly tested a rule based approach for cue competition effects and found no evidence in support of a rule like that proposed above. However, the rule they developed and tested did not make reference to contextual cues, as these were not investigated in their experiments. It remains for further research to determine if rule-based accounts of Pavlovian conditioning that include contextual factors can account for effects such as US omission on elementary trained CSs. In the context of investigating the renewal effect in human participants, the possible impact of rule based approaches to the learning task highlights a potentially important difference between the renewal procedures employed with human and animal subjects (Havermans et al., 2005).

At a practical level, the phenomenon of renewal has been suggested to provide a mechanism that can explain relapse following extinction-based treatments in some cases (e.g., Bouton, 2002). Increasing the number of extinction contexts may reduce the renewal effect by increasing the generalization of extinction training to test contexts because of the greater number of shared cues. It may also provide the individual with the impression that the CS is now safe in every context (Gunther et al., 1998). As predicted by this conceptualization, both the renewal effect observed in the ABA design and the increase in suppression in the ABC design were abolished when extinction was conducted in multiple contexts. The implication for the application of extinction-based treatments for behavior problems is that conducting therapy in multiple contexts might help reduce relapse (Chelonis et al., 1999; Gunther et al., 1998). It is important to note that in the present experiments, the acquisition trials were presented in only one context. Gunther et al. (1998, Experiment 2) examined the relationship between the number of acquisition contexts and extinction contexts on ABC renewal. When acquisition was

conducted in one context followed by extinction in multiple contexts, the renewal effect was abolished. This design is analogous to the ABC Multiple Extinction Context group used in the present research. However, when acquisition was conducted in several contexts, followed by extinction in several contexts, the renewal effect was not abolished. Gunther et al. (1998) suggested that renewal might only be abolished when there are a greater number of extinction contexts relative to acquisition contexts. Examining the relationship between the number of contexts in each experimental phase is beyond the scope of the present experiments but can be investigate in subsequent research.

References

- Arcediano, F., Ortega, N.; Matute, H. (1996). A behavioural preparation for the study of human Pavlovian conditioning. *Quarterly Journal of Experimental Psychology: Comparative & Physiological Psychology*, 49B, 270-283.
- Bouton, M. E. (1984). Differential control by context in the inflation and reinstatement paradigms. *Journal of Experimental Psychology: Animal Behavior Processes*, 10, 56-74.
- Bouton, M. E. (1986). Slow reacquisition following the extinction of conditioned suppression. *Learning and Motivation*, 17, 1-15.
- Bouton, M. E. (1993). Context, time, and memory retrieval in the interference paradigms of Pavlovian learning. *Psychological Bulletin*, 114, 80-99.
- Bouton, M. E. (2002). Context, ambiguity, and unlearning: Sources of relapse after behavioral extinction. *Biological Psychiatry*, 52, 976-986.
- Bouton, M. E., & Bolles, R. C. (1979). Contextual control of the extinction of conditioned fear. *Learning and Motivation*, 10, 445-466.
- Bouton, M. E., & King, D. A. (1983). Contextual control of the extinction of conditioned fear: Tests for the associative value of the context. *Journal of Experimental Psychology: Animal Behavior Processes*, 9, 248-265.
- Bouton, M. E., & Nelson, J. B. (1994). Context-specificity of target versus feature inhibition in a feature-negative discrimination. *Journal of Experimental Psychology: Animal Behavior Processes*, 20, 51-65.
- Bouton, M.E., & Nelson, J. B. (1998). Context in classical conditioning. In *Learning and Behavior Therapy* (pp. 59-84). Needham Heights, MA: Allyn & Bacon.

- Bouton, M. E., & Peck, D. A. (1989). Context effects on conditioning, extinction, and reinstatement in an appetitive conditioning preparation. *Animal Learning and Behavior*, 17, 188-198.
- Branch, M. N., Hackenberg, T. D. (1998). Humans are animals, too: Connecting animal research to human behavior and cognition. In W.T. O'Donohue, (Ed). *Learning and Behavior Therapy* (pp. 15-35). Needham Heights, MA, US: Allyn & Bacon.
- Chambless, D. L., & Ollendick, T. H. (2001). Empirically supported psychological interventions: Controversies and evidence. *Annual Review of Psychology*, 52, 685-716.
- Chelonis, J. J., Calton, J. L., Hart, J. A., & Schachtman, T. R. (1999). Attenuation of the renewal effect by extinction in multiple contexts. *Learning and Motivation*, 30, 1-14.
- Collins, B. N., & Brandon, T. H. (2002). Effects and extinction context and retrieval cues on alcohol cue reactivity among non-alcoholic drinkers. *Journal of Consulting and Clinical Psychology*, 70, 390-397.
- Craske, M. G., & Rowe, M. (1997). A comparison of behavioural and cognitive treatments of phobias. In G. Davey (Ed.), *Phobias: A handbook of theory, research, and treatment* (pp. 247-280). Chichester: John Wiley
- Games, P. A. (1977). An Improved t Table for Simultaneous Control on g Contrasts. *Journal of the American Statistical Association*, 72, 531 -534.
- Gunther, L. M., Denniston, J. C., & Miller, R. R. (1998). Conducting exposure techniques in multiple settings can prevent relapse. *Behavior Research Therapy*, 36, 75-91.
- Harris, J. A., Jones, M. L., Bailey, G. K., & Westbrook, R. F. (2000). Contextual control over conditioned responding in an extinction paradigm. *Journal of Experimental Psychology: Animal Behavior Processes*, 26, 174-185.

- Havermans, R. C., Keuker, J., Lataster, T., Jansen, A. (2005). Contextual control of extinguished conditioned performance in humans. *Learning and Motivation*, 36, 1-19.
- Johnson, D. M., Baker, J. D., Azorlosa, J. J. (2000). Acquisition, extinction, and reinstatement of Pavlovian fear conditioning: The roles of the NMDA receptor and nitric oxide. *Brain Research*, 857, 66-70.
- Lipp, O. V., & Dal Santo, L. A. (2002). Cue competition between elementary trained stimuli: US miscuing, interference, and US omission. *Learning and Motivation*, 33, 327-346.
- Matute, H., & Pineño, O. (1998). Cue competition in the absence of compound training: its relation to paradigms of interference between outcomes. In D. L. Medin (Ed.), *The Psychology of Learning and Motivation* (Vol. 38) (pp. 45-81). San Diego: Academic Press.
- Mineka, S., Mystkowski, J. L., Hladek, D., & Rodriguez, B. (1999). The effects of changing contexts on return of fear following exposure therapy for spider fear. *Journal of Consulting and Clinical Psychology*, 67, 599-604.
- Mystkowski, J. L., Craske, M. G., & Echiverri, A. M. (2002). Treatment context and return of fear in spider phobia. *Behavior Therapy*, 33, 300-416.
- Mystkowski, J. L, Mineka, S., Vernon, L. L., & Zinbarg, R. E. (2003). Changes in caffeine states enhance return of fear in spider phobia. *Journal of Consulting and Clinical Psychology*, 71, 243-250.
- Nakajima, S., Tanaka, S., Urushihara, K., & Imada, H. (2000). Renewal of extinguished lever-press responses upon return to the training context. *Learning and Motivation*, 31, 416-431.

- Nakajima, S., Urushihara, K., & Masaki, T. (2002). Renewal of operant performance formerly eliminated by omission or noncontingency training upon return to the acquisition context. *Learning and Motivation, 33*, 510-525.
- Ollendick, T. H., & King, N. J. (1991). Origins of childhood fears: An evaluation of Rachman's theory of fear acquisition. *Behaviour Research and Therapy, 29*, 117-123.
- Ortega, N., & Matute, H. (2000). Interference between elementary trained stimuli can take place in one trial. *Learning and Motivation, 31*, 323-344.
- Öst, L. G. (1997). Rapid treatment of specific phobias. In G. Davey (Ed.), *Phobias: A handbook of theory, research, and treatment* (pp. 227-246). Chichester: John Wiley.
- Pavlov, I. P. (1927). *Conditioned reflexes*. New York: Dover.
- Pineño, O., & Matute, H. (2000). Interference in human predictive learning when associations share a common element. *International Journal of Comparative Psychology, 13*, 16-33.
- Rachman, S. J. (1989). The return of fear: Review and prospect. *Clinical Psychology Review, 9*, 147-168.
- Rodriguez, B., Craske, M. G., Mineka, S., & Hladek, D. (1999). Context-specificity of relapse: Effects of therapist and environmental context on return of fear. *Behavior Research Therapy, 37*, 845-862.
- Rosas, J.M., & Bouton, M. E. (1997). Renewal of a conditioned taste aversion upon return to the conditioning context after extinction in another one. *Learning and Motivation, 28*, 216-230.
- Rosas, J. M., Vila, N. J., Logu, M., & López, L. (2001). Combined effect of context change and retention interval on interference in causality judgments. *Journal of Experimental Psychology: Animal Behavior Processes, 27*, 153-164.

Wilson, A., Brooks, D. C., & Bouton, M. E. (1995). The role of the rat hippocampal system in several effects of context in extinction. *Behavioral Neuroscience*, 109, 828-836.

Wolpe, J. (1958). *Psychotherapy by reciprocal inhibition*. Stanford, CA: Stanford University Press.

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Figures

Figure 1. Mean conditioned suppression ratio for the Control group (top panel) and ABA Renewal group (bottom panel) in Experiment 1. Trials A1 to A9 represent the nine trials in the acquisition phase, trials E1 to E9 represent the nine trials in the extinction phase, and trials T1 to T3 represent the three trials in the test phase.

Figure 2. Mean conditioned suppression ratio for the Control group (top panel) and ABC Renewal group (bottom panel) in Experiment 2. Trials A1, A5, A9, A13, and A17 represent the five 3 s trials in the acquisition phase, trials E1, E5, E9, E13, E17, and E21 represent the six 3 s trials in the extinction phase, and trials T1, T2, and T3 represent the three 3 s trials in the test phase.

Figure 3. Mean conditioned suppression ratio for the Control group (top panel), ABA Renewal group (middle panel), and ABA Multiple Extinction Context Renewal group (bottom panel) in Experiment 3. Trials A1, A5, A9, A13, and A17 represent the five 3 s trials in the acquisition phase, trials E1, E5, E9, E13, E17, and E21 represent the six 3 s trials in the extinction phase, and trials T1, T2, and T3 represent the three 3 s trials in the test phase.

Figure 4. Mean conditioned suppression ratio for the Control group (top panel), ABC Renewal group (middle panel), and ABC Multiple Extinction Context Renewal group (bottom panel) in Experiment 3. Trials A1, A5, A9, A13, and A17 represent the five 3 s trials in the acquisition phase, trials E1, E5, E9, E13, E17, and E21 represent the six 3 s trials in the extinction phase, and trials T1, T2, and T3 represent the three 3 s trials in the test phase.

Control Group **ABC Renewal Group**