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Publication Date

2018-03-01

DOI

10.1016/j.jbtep.2017.07.003

Peer reviewed

J. Behav. Ther. & Exp. Psychiat. 58 (2018) 18–28

Contents lists available at ScienceDirect

Journal of Behavior Therapy and Experimental Psychiatry

journal homepage: www.elsevier.com/locate/jbtep

Building physiological toughness: Some aversive events during extinction may attenuate return of fear

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ARTICLE INFO

Article history:
Received 16 May 2016
Received in revised form
22 July 2017
Accepted 23 July 2017
Available online 25 July 2017

Keywords:
Anxiety
Exposure
Relapse prevention
Reinforced extinction

ABSTRACT

Background and objectives: Although exposure therapy is an effective treatment for anxiety disorders, fear sometimes returns following successful therapy. Recent literature in animal models indicates that incorporating some aversive events into extinction training may offset these return of fear effects.
Methods: The effect of occasional reinforced extinction trials was investigated in a sample of thirty-nine participants using a fear conditioning and extinction paradigm. Participants either underwent traditional extinction procedures during which the conditional stimulus which had been paired with the unconditional stimulus (US) during acquisition training (CS+) was presented alone with no presentations of the US or partially reinforced extinction during which there were several unpredicted CS+/US pairings.
Results: As measured by skin conductance responses, physiological fear responding remained elevated during extinction for participants who experienced partially reinforced extinction; however, these participants demonstrated protection from rapid reacquisition effects. Results from the subjective US-expectancy ratings did not provide evidence of protection against rapid reacquisition in the partially reinforced extinction group; however, there was evidence of protection from spontaneous recovery effects. Lastly, as measured by valence ratings, it was unclear whether partially reinforced extinction provided protection from fear recovery effects.
Limitations: Although participants who experienced partially reinforced extinction demonstrated protection from rapid reacquisition as measured by skin conductance responses, they also demonstrated significantly higher levels of physiological fear responding during extinction which made the results of the spontaneous recovery test more difficult to interpret.
Conclusions: Occasional CS-US pairings during extinction may protect against return of fear effects. Clinical implications are discussed.

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1. Introduction

The behavioral treatment most commonly used in the treatment of specific fears and phobias derives from extinction learning and involves systematic exposure to fear-provoking stimuli in the absence of aversive outcomes. Despite being an effective treatment (Norton & Price, 2007), fear often returns (Craske & Mystkowski, 2006). One possible mechanism for this return of fear is rapid reacquisition, whereby fear responding to the conditional stimulus (CS) returns rapidly following re-pairing of the CS and unconditional stimulus (US) (Kehoe & Macrae, 1997; Napier, Macrae, & Kehoe, 1992; Ricker & Bouton, 1996). For example, anxiety to social situations may reduce as a result of exposure therapy but return quickly after just one subsequent pairing of a social situation with a negative outcome (e.g., rejection). Rapid reacquisition is particularly likely in social anxiety given the relatively common occurrence of negative social outcomes and may explain the high rates of relapse observed in social anxiety disorder (Van Ameringen et al., 2003).

Rapid reacquisition provides further evidence that extinction is not unlearning of the previously learned CS-US association. Instead, extinction is hypothesized to involve new inhibitory learning ("CS-no US") that then competes with the CS-US memory (Bouton, 1993). Retrievability of the CS-US memory may explain return of

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http://dx.doi.org/10.1016/j.jbtep.2017.07.003
0005-7916/Published by Elsevier Ltd.

fear following exposure therapy. In the case of rapid reacquisition, the first CS-US pairing following extinction may trigger retrieval of the CS-US memory and interfere with retrieval of the CS-no US memory, thereby facilitating rapid reacquisition. Clearly, this presents a problem for the successful treatment of anxiety disorders. Thus, investigations aimed at finding methods for attenuating rapid reacquisition are warranted.

Although counterintuitive, a potential method for attenuating rapid reacquisition is to present occasional CS-US pairings during extinction. This has been effective in animal studies using Pavlovian and operant conditioning paradigms (Bouton, Woods, & Pineno, 2004; Woods & Bouton, 2007). With an appetitive conditioning procedure, partially reinforced extinction (some CS-US pairings) slowed the rate of reacquisition compared with nonreinforced extinction, even though this partial reinforcement procedure also slowed the loss of conditional responding during extinction training (Bouton et al., 2004). Similarly, compared with nonreinforced extinction, reacquisition of an operant conditioning response was significantly slower after partially reinforced extinction across three experiments (Woods & Bouton, 2007).

One potential mechanism by which partially reinforced extinction may slow reacquisition is connection of CS-US pairings with the extinction context rather than solely with the acquisition context (Bouton et al., 2004). Specifically, Bouton et al. (2004) suggest that, during acquisition, reinforced trials become associated with other reinforced trials. During extinction, nonreinforced trials become associated with other nonreinforced trials. Following extinction, a reinforced trial (CS-US pairing) will trigger memories of acquisition and lead to a prediction of further CS-US pairings. In contrast, if some CS-US pairings occur during extinction, reinforced trials become associated with *non*reinforced trials (during extinction) and reinforced trials (during acquisition). Thus, a CS-US pairing following extinction becomes more ambiguous and this ambiguity will slow the rate of reacquisition.

Another potential mechanism for the effectiveness of partially reinforced extinction derives from a model of Pavlovian learning in which learning on any given trial is directly proportional to CS intensity, CS salience, and US intensity (Pearce & Hall, 1980). Importantly, CS salience on any given trial is a function of how surprising the outcome was on the previous trial. Following several nonreinforced trials during extinction, a reinforced trial will be especially surprising. Thus, CS salience will be maximized on the following trial and, when the US does not occur, learning regarding the CS-no US relationship will be maximized. This enhanced learning regarding the CS-no US relationship may provide protection from future fear recovery effects. Importantly, the mechanism posited by Bouton and colleagues predicts that partially reinforced extinction will only attenuate rapid reacquisition; however, Pearce and Hall's model predicts attenuation of all fear recovery effects (i.e., spontaneous recovery, rapid reacquisition, renewal, and reinstatement), since learning regarding the CS-no US relationship is maximized.

The current investigation is the first human study of occasional reinforced trials during extinction. Following fear conditioning, participants were randomly assigned to nonreinforced extinction versus partially reinforced extinction (some CS-US pairings). The schedule of partial reinforcement was determined by previous findings (Bouton et al., 2004) which indicated a 2:8 schedule led to greater reduction in reacquisition rates. It was hypothesized that participants in the partial reinforcement group would demonstrate slower loss of conditional fear responding during extinction (as measured by skin conductance responses and subjective US-expectancy ratings) but also significantly slower reacquisition rate. In order to test the prediction of Pearce and Hall's model, a spontaneous recovery test was also included to evaluate whether partially reinforced extinction attenuated fear recovery effects other than rapid reacquisition.

2. Material and methods

2.1. Design

Participants were randomly assigned to one of two experimental groups: Partial Reinforced [PR; n = 19] or Control [C; n = 20].

2.2. Participants

Thirty-nine ethnically diverse (35.3% Asian, 35.3% Caucasian, 17.6% Latino, 5.9% Biracial, 5.9% Indian) participants (30 female), with a mean age of 19.2 (range 18–22), were recruited from Psychology classes. Participants were recruited if they scored in the top quartile on the Behavioral Inhibition Scale (BIS; Carver & White, 1994), to increase generalizability to individuals with a vulnerability to anxiety disorders. Exclusion criteria (which were assessed through self-report) included: 1) heart, respiratory, or neurological problems, 2) current or a history of seizures, and 3) pregnancy.

2.3. Measures

2.3.1. Self report questionnaires

Two self-report measures were completed at Baseline: the BIS (Carver & White, 1994) and the Beck Depression Inventory (BDI; Beck, Steer, & Brown, 1996). The 7-item BIS measures individual differences in the behavioral inhibition system, believed to regulate aversive motives in which the goal is to move away from something unpleasant (Carver & White, 1994). In the current sample, $\alpha = 0.79$. The BDI is a widely used screening instrument for depression with strong psychometric properties (Beck et al., 1996). In the current sample, $\alpha = 0.89$.

2.3.2. Subjective measures

Across all experimental phases, participants rated their expectancy of the scream-US during CS presentations. They recorded US-expectancy at each CS-onset on a scale between −6 = "certain no noise" to +6 = "certain noise" with a midpoint of 0 = uncertain. Participants were trained on this scale and then, prior to the start of each phase, held a pen and placed their dominant hand on the desk on top of an expectancy ratings recording sheet so they could provide ratings with minimal movement. They were instructed to quickly record their expectancy rating when a face appeared on the screen and then immediately return their attention to the screen.

Participants rated valence for each CS from −50 = "very unpleasant" to +50 = "very pleasant" with a midpoint of 0 = "neutral" four times: immediately following acquisition, immediately following extinction, at spontaneous recovery, and following test. At each of these time points, participants were shown the scale and provided these ratings verbally to a trained research assistant who recorded them.

2.3.3. Physiological measures

Skin conductance responses (SCRs) were measured using a Biopac MP150 unit running Acqknowledge 4.0 software (Biopac Systems, Inc., Goleta, CA) with a GSR 100C amplifier set to direct current, a sensitivity of 5 μS/V, and a 1.0-Hz low-pass filter. SCRs were measured at each CS-onset and provided a measure of fear arousal. Data were acquired at 200 samples per second.

To measure SCRs, two disposable 1 cm diameter Ag-AgCl electrodes were placed on the distal phalanx of the index and middle fingers of the non-dominant hand. SCR magnitude was calculated

as the difference between maximum skin conductance level (SCL; measured in microsiemens) within 1–6 s following CS-onset and mean SCL within 2-s prior to CS-onset. Amplitudes were range corrected using each participant's largest response elicited by the US (calculated as the difference between maximum SCL within 1–6 s following US-onset and mean SCL within 2-s prior to CS-onset). For each participant, all SCRs to CSs were divided by maximum SCR to the US; then, square root transformed to normalize the distribution. Movements, including coughing or sneezing were noted so that SCRs could be rejected if behavioral observations indicated movement; however no SCRs were rejected. SCRs were scored as zero when there was no observable peak in SCL within 1–6 s following CS-onset. All SCR scoring was completed by trained research assistants who were blind to participant's experimental group assignment.

2.3.4. Apparatus and stimuli

Two neutral faces from the NimStim set of facial expressions (Tottenham et al., 2009) were used as CSs; one was paired with the US during acquisition training (CS+) while the other was not (CS-); which face served as CS+ versus CS- was counterbalanced across participants. To make facial stimuli relatable to the majority of research participants at UCLA, the faces were of Asian females. The US was a 1-s scream presented binaurally through headphones at 82 dB. Such auditory stimuli have successfully served as USs in previous studies (Lau et al., 2008), demonstrating equivalent or superior conditioning effects as shock USs without the risk of pain (Neumann & Waters, 2006) and producing more robust conditioning effects than a white noise-US (Joos, Vansteenwegen, & Hermans, 2012). Stimulus delivery was controlled by one computer using E-prime software (Psychology Software Tools, Inc., Pittsburgh, PA, USA) while physiological data acquisition was controlled by a second computer using Acqknowledge software (Biopac Systems, Inc., Goleta, CA).

2.4. Procedure

The experiment consisted of several phases completed over two days (Table 1). All procedures were approved by the UCLA Institutional Review Boards. On Day 1, a trained research assistant described the study procedures, obtained informed consent, and administered the BIS and BDI. Electrodes were attached for recording SCR. Next, psychophysiological measures were recorded for a 5-min *baseline* during which participants were instructed to "please sit quietly and remain still" and left alone in the room (physiological data acquisition was monitored from an adjacent room). Following baseline, participants were seated 3 feet in front of a 21″ computer monitor placed at eye level, told "*You will be seeing faces on the screen and may occasionally hear a loud noise,*" and reminded to record expectancy of hearing the noise each time a face appeared. Across all phases, CSs were presented in random order with the caveat of no more than two trials of each CS in consecutive position. The inter-trial interval (ITI) varied across 20, 25, and 30 seconds (mean = 25 seconds). Participants underwent *habituation*: four 8-s presentations of each CS. Next, participants underwent *acquisition*: eight 8-s presentations of each CS; during the last second of each CS+, the scream-US was presented through the headphones. Following acquisition, participants removed the headphones and provided CS valence ratings. They then replaced the headphones and, after another 5-min *baseline*, commenced *extinction*, involving twenty-four 8-s CS+ and CS- presentations. For group C participants, there were no US presentations; for group PR participants, two out of every eight CS+ trials were reinforced. To distribute these reinforced CS+ presentations, extinction was divided into three blocks of eight trials, each of which contained two reinforced trials. Within each block, reinforced trials occurred during Trials 2 and 6, 3 and 7, or 4 and 8; two reinforced trials never occurred consecutively. Following extinction, participants again provided CS valence ratings.

Day 2, one week later, assessed spontaneous recovery and reacquisition. First, participants provided CS valence ratings. Electrodes were attached as during Day 1, participants sat in front of the same monitor wearing the same headphones, and were instructed to record US-expectancy ratings at each CS-onset. Participants underwent *spontaneous recovery test*: four 8-s nonreinforced CS+ and CS- presentations. Then, they underwent *reacquisition*: four 8-s CS+ presentations paired with the US and four 8-s CS- presentations. Lastly, participants underwent *retest*: four 8-s CS+ and CS- presentations. These three phases occurred consecutively without interruption. Upon completion, participants provided CS valence ratings.

2.5. Statistical analyses

Baseline differences were examined using independent samples t-tests. Regression analyses and their follow-up tests were conducted using hierarchical linear modeling (HLM; Raudenbush & Bryk, 2002). HLM is useful in analyzing repeated measures data (Level 1 data) nested within subjects (Level 2 data; Bryk, Raudenbush, & Congdon, 1996). HLM does not require the assumption of independence of observations, improves the estimate of effects within individual units, and has lower Type I error rates (Raudenbush & Bryk, 2002). HLM essentially conducts regressions and is capable of including fixed factors (independent variables) and multiple random factors (e.g., individuals). It was used in this study to examine change across time with repeated measures for each individual. T-tests were used to examine whether y-intercepts of regression lines were significantly different from zero and whether differences between two regression lines (e.g., regression line for change in SCR to CS+ in group PR versus group C during extinction) were significant.

3. Results

For HLM and ANOVA analyses, please see supplemental section for statistical values of nonsignificant results. Trials are

Table 1
Experimental phases completed during Day 1 and Day 2.

Group	Day 1			Day 2		
	Habituation	Conditioning	Extinction	Spontaneous recovery	Reacquisition	Retest
Control	CS+ (4) CS− (4)	CS+ + US (8) CS− (8)	CS+ (24) CS− (24)	CS+ (4) CS− (4)	CS+ + US (4) CS- (4)	CS+ (4) CS− (4)
Partial Reinforced	CS+ (4) CS− (4)	CS+ + US (8) CS− (8)	CS+ (24)[a] CS− (24)	CS+ (4) CS− (4)	CS+ + US (4) CS- (4)	CS+ (4) CS− (4)

[a] 2:8 Partial Reinforcement Schedule, 6 total CS+ + US pairings.

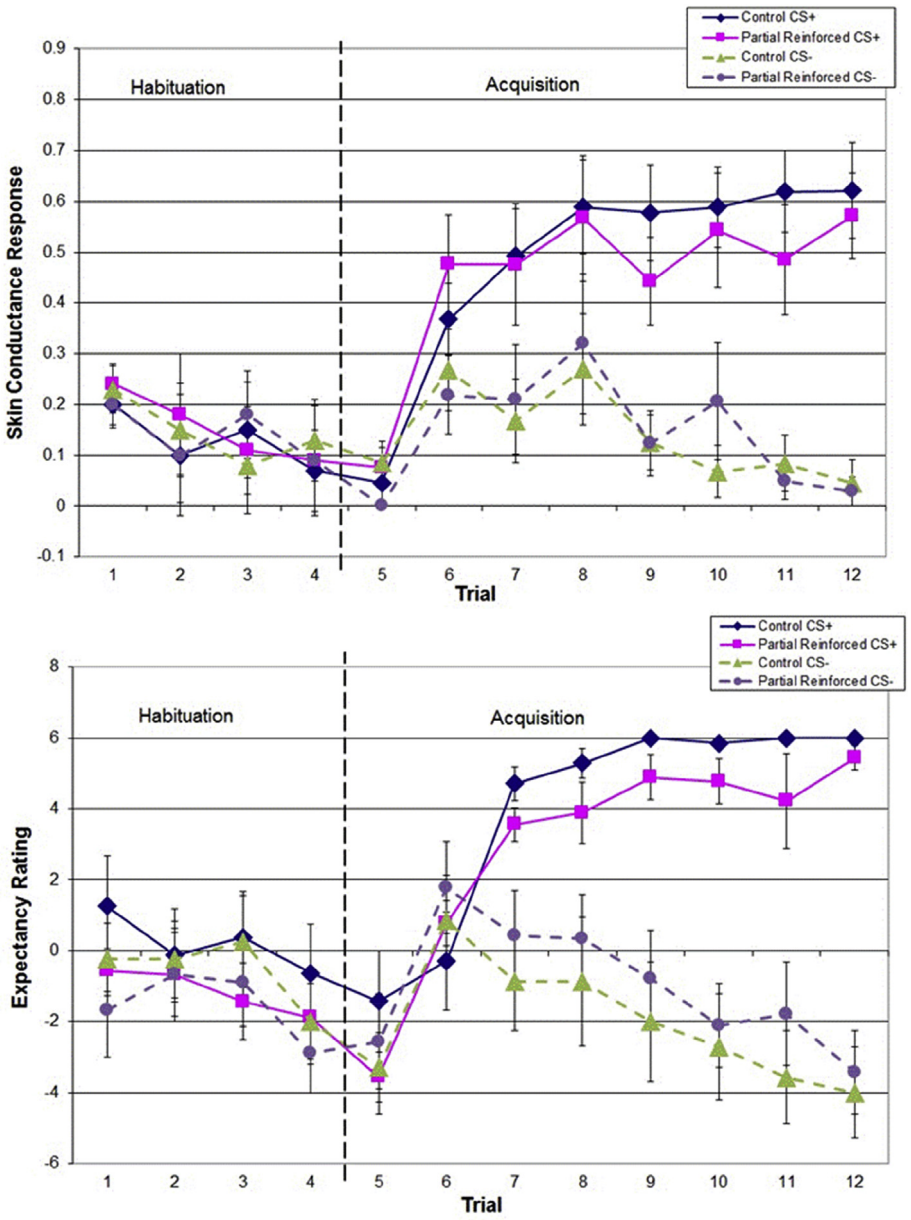

Fig. 1. Mean SCRs and US-expectancy ratings to CS+ and CS− during habituation and acquisition in Control versus Partial Reinforced groups.

conceptualized as "Time" and "CS Type" indicates whether there were differences in responding to CS+ versus CS-.

3.1. Baseline

Mean BIS was 23.35 and mean BDI was 6.82. Independent samples t-tests revealed no significant between-group differences in BIS ($t(37) = 0.34$, $p = 0.74$), BDI ($t(37) = 1.43$, $p = 0.17$), age ($t(37) = 1.39$, $p = 0.19$), gender ($\chi^2(1, N = 39) = 1.02$ ($p = 0.31$)), or ethnicity ($\chi^2(4, N = 39) = 2.95$ ($p = 0.57$)).

3.2. Habituation

There were no significant findings (Fig. 1).

3.3. Acquisition

3.3.1. Skin conductance response (SCR)

For all participants, SCR at the first acquisition trial was significantly greater than zero ($b = 0.26$, $t(74) = 3.53$, $p < 0.005$, $d = 0.82$). There was a significant effect of Time ($b = 0.04$, $t(542) = 3.23$, $p < 0.01$, $d = 0.28$) and CS Type × Time interaction ($b = -0.05$, $t(542) = -2.97$, $p = 0.01$, $d = 0.26$); since CS+ was coded as 0 and CS- as 1, this interaction t-value indicates all participants demonstrated an increase in physiological fear responding to CS+ but not CS- across acquisition (Fig. 1).

3.3.2. Expectancy ratings

There was a significant effect of Time ($b = 1.01$, $t(542) = 6.37$, $p < 0.001$, $d = 0.26$) and Time x CS Type ($b = -1.40$, $t(542) = -6.10$, $p < 0.001$, $d = 0.12$) with the t-value indicating all participants

demonstrated an increase in US-expectancies to CS+ but not CS- across acquisition (Fig. 1).

3.4. Extinction

3.4.1. Skin conductance response (SCR)

For all participants, SCR at the first extinction trial was significantly greater than zero (b = 0.44, t(74) = 4.93, p < 0.001, d = 1.15). There was a significant group difference in Time (b = −0.02, t(542) = -4.45, p < 0.001, d = 0.38), CS Type (b = −0.21, t(542) = -3.04, p < 0.01, d = 0.26), and Time x CS Type × Group interaction (b = 0.02, t(542) = 2.87, p = 0.01, d = 0.25). Tests of simple effects were conducted to analyze this interaction effect. For CS+, Time was significant (b = −0.02, t(895) = -7.23, p < 0.001, d = 0.48) with a significant group difference (b = 0.02, t(895) = 5.04, p < 0.001, d = 0.34) indicating physiological fear responding to CS+ decreased in group C but not PR across extinction. For CS-, Time was significant (b = −0.01, t(895) = -3.00, p < 0.005, d = 0.20) with no group differences, indicating all participants demonstrated a decrease in physiological fear responding to CS- across extinction (Fig. 2).

3.4.2. Expectancy ratings

For all participants, US-expectancy at the first extinction trial was significantly greater than zero (b = 2.36, t(74) = 3.12, p < 0.01, d = 0.55). There was a significant group difference in Time (b = −0.33, t(542) = -5.83, p < 0.001, d = 0.50), CS Type (b = −3.68, t(542) = -3.06, p < 0.01, d = 0.32), Time x CS Type interaction (b = −0.20, t(542) = -2.58, p < 0.05, d = 0.22), and Time x CS Type × Group interaction (b = 0.36, t(542) = 3.19, p < 0.01, d = 0.27). For CS+, Time was significant (b = −0.30, t(895) = -6.29, p < 0.001, d = 0.42) with a significant group difference (b = 0.33, t(895) = 6.01, p < 0.001, d = 0.40) indicating group C participants

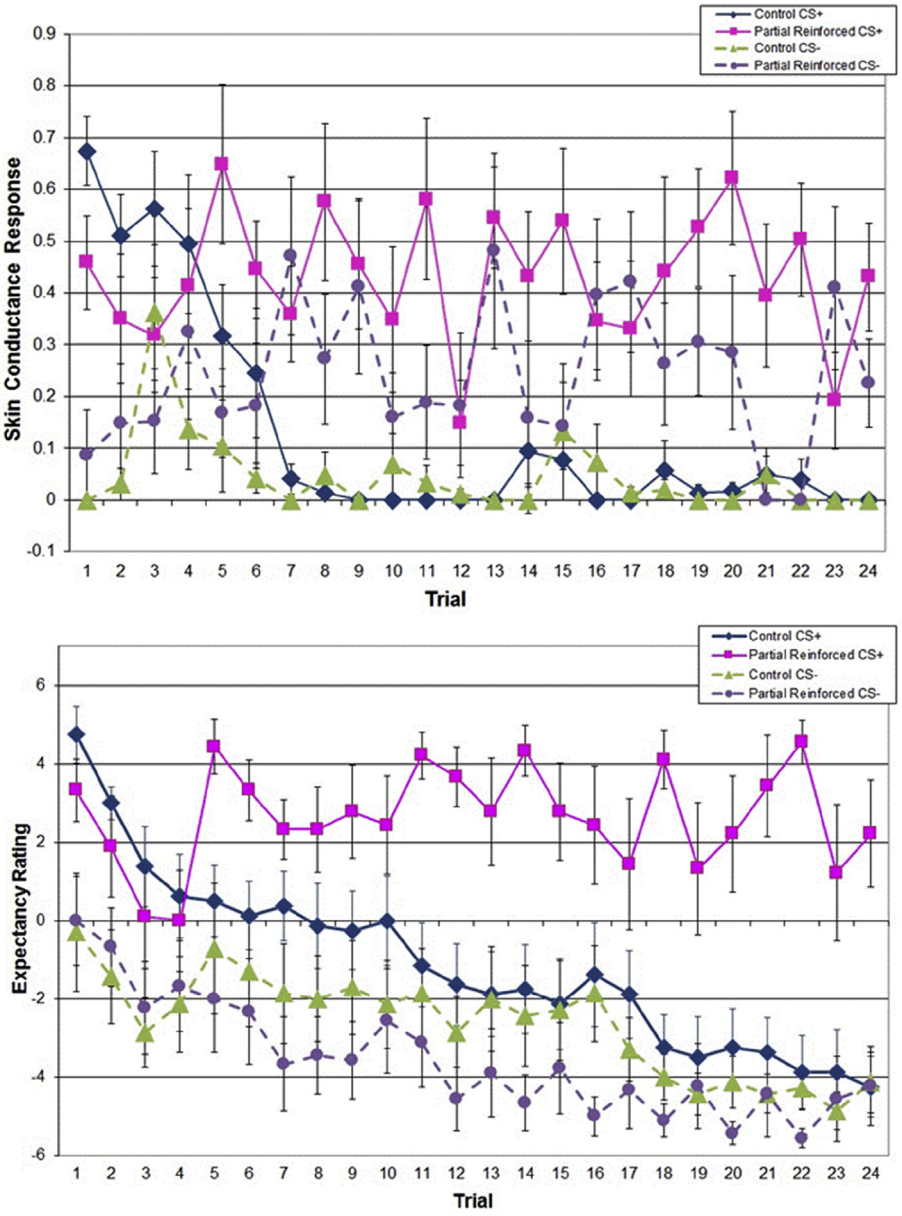

Fig. 2. Mean SCRs and US-expectancy ratings to CS+ and CS− during extinction in Control versus Partial Reinforced groups. For PR Group, reinforced CS+ trials occurred at trials 4, 8, 11, 15, 18, and 22.

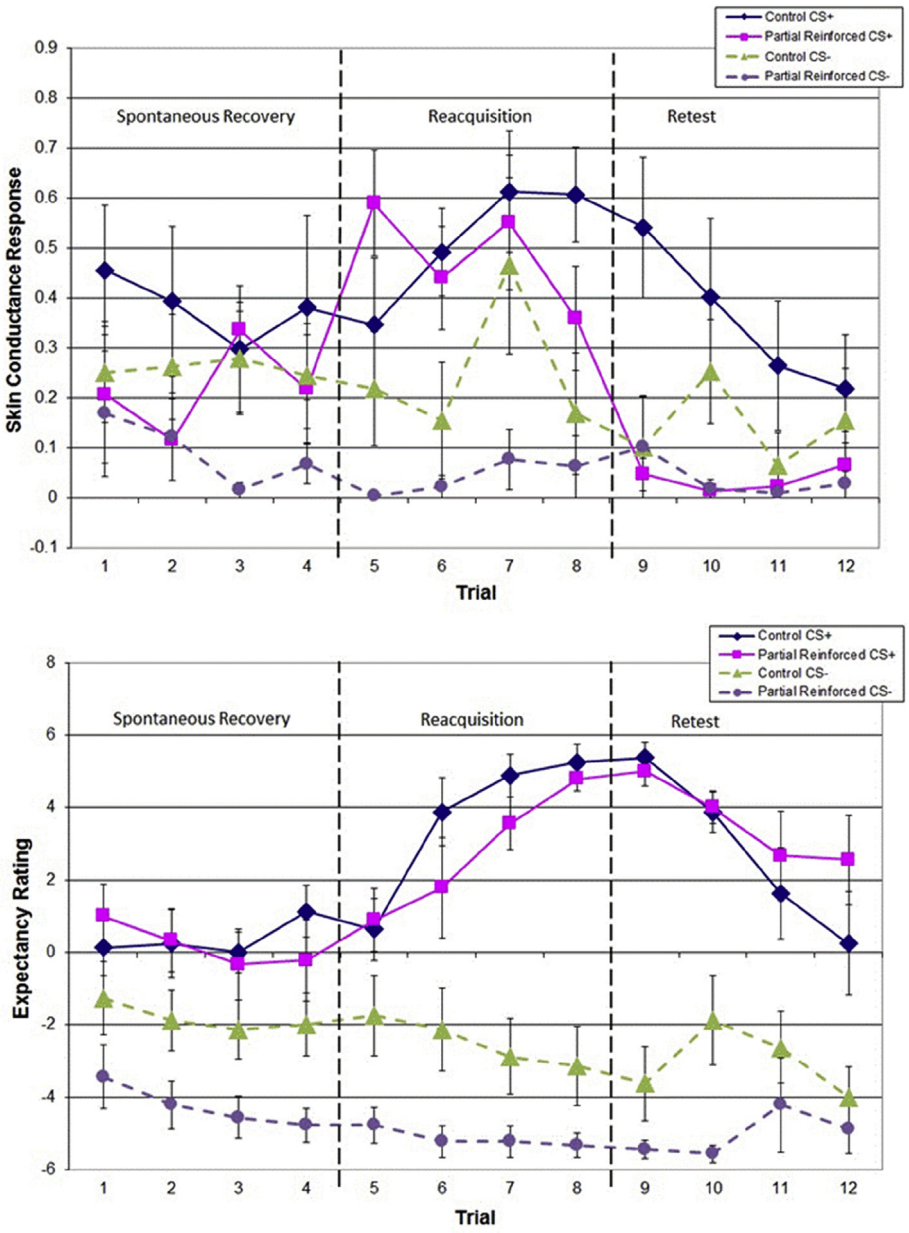

Fig. 3. Mean SCRs and US-expectancy ratings to CS+ and CS− spontaneous recovery, reacquisition, and retest in Control versus Partial Reinforced groups.

demonstrated a decline in US-expectancies across extinction whereas group PR participants did not. For CS-, Time was significant ($b = -0.14$, $t(895) = -6.78$, $p < 0.001$, $d = 0.45$) with no group differences indicating all participants demonstrated a decrease in US-expectancies to CS- across extinction (Fig. 2).

3.5. Spontaneous recovery test

3.5.1. Skin conductance response (SCR) and expectancy ratings

The only significant finding was for CS Type of US-expectancies ($b = -4.61$, $t(895) = -3.22$, $p < 0.01$, $d = 0.22$) indicating significantly lower US-expectancies for CS- than CS+ across all participants (Fig. 3).

3.6. Spontaneous recovery test: change from last trial of extinction to first trial of spontaneous recovery

3.6.1. Skin conductance response (SCR)

A 2(Group: Control, Partial Reinforced) x 2(Time: Last Trial of Extinction, First Trial of Spontaneous Recovery) x 2(CS Type: CS+, CS-) repeated measures ANOVA revealed a significant Time × Group interaction ($F(1,72) = 10.11$, $p < 0.01$, $\eta_p^2 = 0.44$) and Time x Group x CS Type interaction ($F(1,72) = 8.68$, $p < 0.01$, $\eta_p^2 = 0.40$). Tests of simple effects revealed group C participants demonstrated a significant increase in SCRs to CS+ from Last Trial of Extinction to First Trial of Spontaneous Recovery ($F(1,37) = 10.63$, $p < 0.01$, $\eta_p^2 = 0.45$) whereas group PR participants demonstrated no change (Fig. 4).

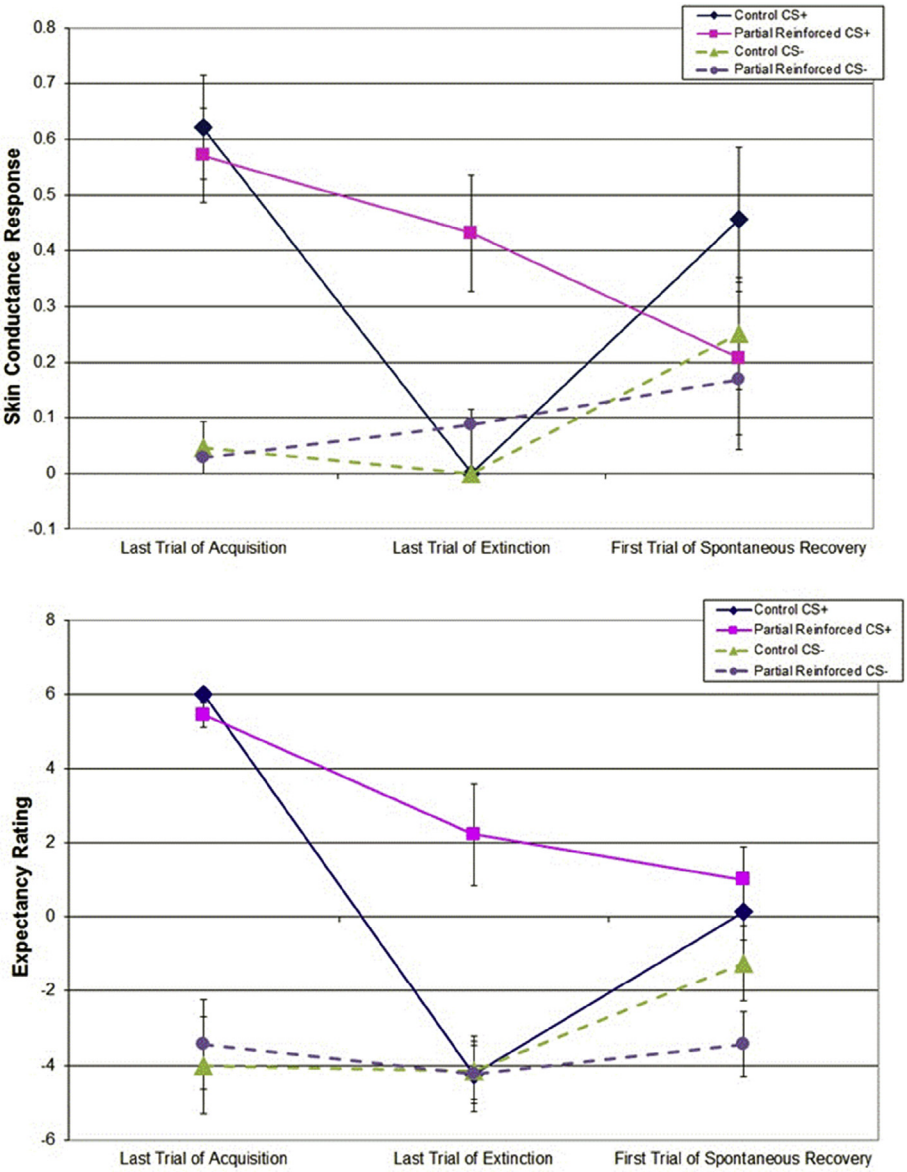

Fig. 4. Mean SCRs and US-expectancy ratings at the last trial of acquisition training, the last trial of extinction training, and the first trial of spontaneous recovery in Control versus Partial Reinforced groups.

3.6.2. Expectancy ratings

A 2(Group: Control, Partial Reinforced) x 2(Time: Last Trial of Extinction, First Trial of Spontaneous Recovery) x 2(CS Type: CS+, CS-) repeated measures ANOVA revealed a significant Time × Group interaction ($F(1,72) = 7.44$, $p < 0.05$, $\eta_p^2 = 0.33$) and Time x Group x CS Type interaction ($F(1,72) = 14.03$, $p < 0.01$, $\eta_p^2 = 0.48$). Tests of simple effects revealed group C participants demonstrated a significant increase in US-expectancies to CS+ ($F(1,37) = 8.59$, $p = 0.01$, $\eta_p^2 = 0.36$) and CS- ($F(1,37) = 6.63$, $p < 0.05$, $\eta_p^2 = 0.32$) from Last Trial of Extinction to First Trial of Spontaneous Recovery whereas group PR participants demonstrated no change (Fig. 4).

3.7. Spontaneous recovery test: change from last trial of acquisition to first trial of spontaneous recovery

3.7.1. Skin conductance response (SCR)

A 2(Group: Control, Partial Reinforced) x 2(Time: Last Trial of Acquisition, First Trial of Spontaneous Recovery) x 2(CS Type: CS+, CS-) repeated measures ANOVA revealed a significant effect of Time x CS Type ($F(1,72) = 7.81$, $p < 0.05$, $\eta_p^2 = 0.39$); tests of simple effects indicated participants across both groups demonstrated a significant decrease in SCRs to CS+ from Last Trial of Acquisition to First Trial of Spontaneous Recovery ($F(1,37) = 7.66$, $p < 0.05$, $\eta_p^2 = 0.37$) but no change in SCRs to CS- (Fig. 4).

3.7.2. Expectancy ratings

A 2(Group: Control, Partial Reinforced) x 2(Time: Last Trial of Acquisition, First Trial of Spontaneous Recovery) x 2(CS Type: CS+, CS-) repeated measures ANOVA revealed a significant effect of Time x CS Type ($F(1,72) = 78.86$, $p < 0.001$, $\eta_p^2 = 0.84$); tests of simple effects indicated participants across both groups demonstrated a significant decrease in US-expectancies to CS+ from Last Trial of Acquisition to First Trial of Spontaneous Recovery ($F(1,37) = 77.62$, $p < 0.001$, $\eta_p^2 = 0.82$) but no change in US-expectancies to CS- (Fig. 4).

3.8. Reacquisition test

3.8.1. Skin conductance response (SCR)

There was a significant Time x CS Type × Group interaction ($b = -0.38$, $t(542) = -2.34$, $p < 0.05$, $d = 0.20$). For CS+, there was a significant effect of Time ($b = 0.09$, $t(115) = 2.32$, $p < 0.05$, $d = 0.43$) with a significant group difference ($b = -0.15$, $t(115) = -2.70$, $p = 0.01$, $d = 0.50$) indicating group PR demonstrated a decrease in physiological fear responding across reacquisition while group C demonstrated an increase. For CS-, there were no significant findings (Fig. 3).

3.8.2. Expectancy ratings

For all participants, US-expectancies were significantly lower than zero at first trial of reacquisition ($b = -6.18$, $t(74) = -2.51$, $p < 0.05$, $d = 0.58$). There was a significant effect of Time ($b = 1.38$, $t(542) = 4.42$, $p < 0.001$, $d = 0.38$), CS Type ($b = -4.06$, $t(542) = -3.09$, $p < 0.01$, $d = 0.27$) and Time x CS Type interaction ($b = -1.54$, $t(542) = -3.87$, $p < 0.005$, $d = 0.33$) indicating a greater increase in US-expectancies to CS+ than CS- across reacquisition for all participants (Fig. 3).

3.9. Retest

3.9.1. Skin conductance response (SCR)

There was a significant Time x CS Type × Group interaction ($b = -0.14$, $t(542) = -1.91$, $p < 0.05$, $d = 0.16$). For CS+, Time was significant ($b = 1.56$, $t(115) = 2.09$, $p = 0.05$, $d = 0.39$) with a significant group difference ($b = -0.56$, $t(115) = -2.50$, $p < 0.05$, $d = 0.47$) indicating group C demonstrated a decrease in physiological fear responding while group PR did not. For CS-, there were no significant findings (Fig. 3).

3.9.2. Expectancy ratings

All participants demonstrated US-expectancies greater than zero at first trial of Retest ($b = 12.66$, $t(74) = 2.44$, $p < 0.05$, $d = 0.57$). There was also a significant effect of CS Type ($b = -11.50$, $t(542) = -7.66$, $p < 0.001$, $d = 0.66$) indicating a greater decline in US-expectancies to CS+ than CS- across retest for all participants.

3.10. Valence ratings

A 4(Time: Post-Acquisition, Post-Extinction, Spontaneous Recovery, and Post-Test) x 2(Group: Control, Partial Reinforced) x 2(CS Type: CS+, CS-) repeated measures ANOVA revealed significant effects of Time ($F(3,72) = 7.67$, $p < 0.001$, $\eta_p^2 = 0.28$), Time x Group ($F(3,72) = 3.22$, $p < 0.05$, $\eta_p^2 = 0.14$), Time x CS Type ($F(3,72) = 5.81$, $p = 0.001$, $\eta_p^2 = 0.23$), and Time x Group x CS Type ($F(3,72) = 4.44$, $p < 0.01$, $\eta_p^2 = 0.18$; Fig. 5). Tests of simple effects revealed that, from Post-Acquisition to Post-Extinction, participants in group C demonstrated a significant increase in valence ratings to CS+ ($F(1,19) = 31.41$, $p < 0.001$, $\eta_p^2 = 0.68$) while group PR participants demonstrated no change. From Post-Acquisition to Post-Extinction, all participants demonstrated a significant increase in valence ratings to CS- ($F(1,37) = 5.05$, $p < 0.05$, $\eta_p^2 = 0.14$). From Post-Extinction to Spontaneous Recovery, all participants demonstrated a significant decrease in valence ratings to CS- ($F(1,37) = 12.05$, $p < 0.01$, $\eta_p^2 = 0.28$).

4. Discussion

This study tested the hypothesis that occasional reinforced trials during extinction would lead to decreased fear recovery one week later. Based on results and the model posited by Bouton et al. (2004), it was hypothesized that partially reinforced extinction would attenuate rapid reacquisition. In addition, based on the predictions of Pearce and Hall's model, it was hypothesized that occasional reinforced extinction trials would attenuate spontaneous recovery effects. The current results provide preliminary evidence for these hypotheses.

In regards to the rapid reacquisition test, we hypothesized that Partial Reinforced group participants would show a flatter positive slope than the Control group. However, the skin conductance results indicated even more powerful effects than predicted since Partial Reinforced group participants did not demonstrate reacquisition at all. In fact, the Partial Reinforced group demonstrated a *decline* in physiological responding during reacquisition whereas the Control group demonstrated an increase. These effects cannot be fully explained by Bouton's model or Pearce and Hall's model. One potential explanation derives from the “toughening up”

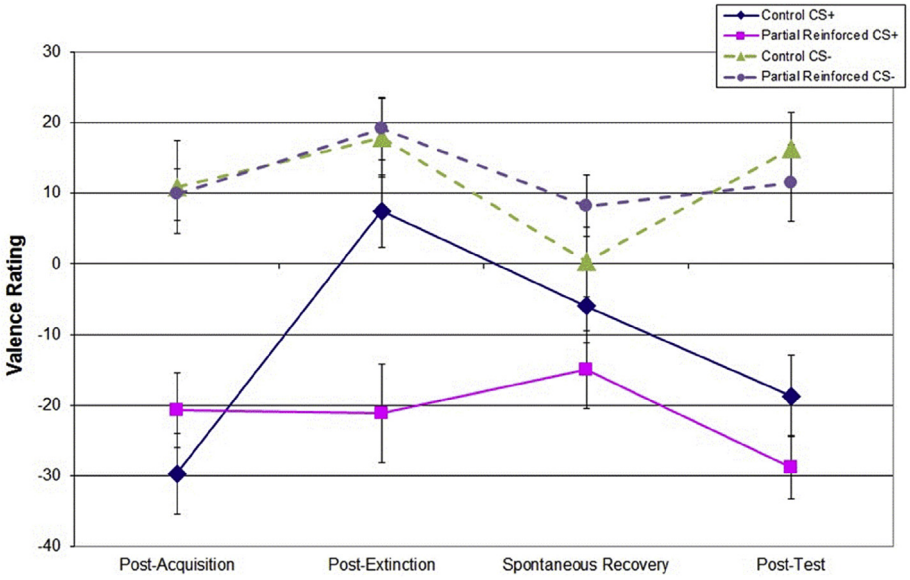

Fig. 5. Valence ratings to CS+ and CS− across four time points: post-acquisition, post-extinction, spontaneous recovery, and post-test.

literature in animal models (Weiss & Glazer, 1975). Weiss and colleagues found that animals given recovery periods between repeated stressors (e.g., cold-water swimming, uncontrollable shock) did not demonstrate the same learned helplessness phenomenon that results from repeated uncontrolled stressors (Weiss, Glazer, Pohorecky, Brick, & Miller, 1975). In fact, the brain tissue of these "toughened" animals demonstrated specific changes indicating resistance to the catecholamine depletion that characterizes learned helplessness. Further, there is evidence in animals and humans that, in addition to resistance in central catecholamine depletion, physiological toughness increases peripheral catecholamine availability and beta-receptor sensitivity, and leads to suppression of cortisol responses (reviewed in Deinstbier, 1989). Physiological toughness may allow the organism to appraise the situation and decide upon the most efficient coping method (Deinstbier, 1989). Conceivably, the Partial Reinforced extinction procedure led to a similar type of physiological toughness. Hence, during the reacquisition test, participants may have engaged in the most adaptive response available: palliative coping (i.e., control of emotional responses; Deinstbier, 1989). Since they learned during extinction that they could not predict whether or not the CS+ would be followed by the US, perhaps they learned to tolerate this distress and to cope by controlling their emotional response and arousal during the reacquisition test.

The skin conductance results during reacquisition may also be related to a body of literature indicating that patients with anxiety disorders exhibit greater startle responses to unpredictable, but not predictable, threat compared with controls (e.g., Grillon et al., 2008). And, in fact, palliative coping or physiological non-responsiveness may be one of the strategies used to tolerate this heightened distress regarding unpredictable threat: anxiety disorders often co-occur with alcohol abuse/dependence and there is evidence that alcohol selectively reduces reactivity to unpredictable threat (Cosci, Schruers, Abrams, & Griez, 2007; Hefner & Curtin, 2012). Since neither startle responses nor anxiety ratings during CS presentations were measured in this study, it is difficult to draw conclusions regarding this possibility but important to investigate in future studies.

In regards to US-expectancy ratings, there were no differences between the groups during reacquisition. It is unclear what led to this discrepancy between subjective ratings and physiological responding. There is an entire body of research indicating conditioning can occur without contingency awareness (e.g., Schultz & Helmstetter, 2010). Such studies provide evidence for a dual process model of learning (Squire, 1992) in which exposure to the experimental contingencies results in two independent learning processes: propositional learning that leads to an awareness of the contingencies and a conditional process which leads to the production of an autonomic conditional response (CR). A dual process theory of learning allows for dissociation between the implicit and explicit process; thus, allowing for the possibility that PR group participants in the current study learned the explicit contingency between CS+ and US during reacquisition while not being physiologically conditioned to produce an autonomic CR perhaps because the unpredictable extinction procedure had taught them that the most effective strategy was palliative coping and tolerating distress. It should be noted that dual process theories of learning are usually used to account for differential physiological responding to CS+ versus CS- in the absence of subjective contingency awareness (e.g., Lovibond & Shanks, 2002). However, the current results indicate subjective contingency awareness of the CS+ versus CS- without differential physiological fear responding. However, if these two process of learning occur separately, it does seem possible that PR group participants were aware of contingency between CS+ and US during reacquisition but were not physiologically conditioned to the CS+ due to the partially reinforced extinction procedure they experienced.

The spontaneous recovery effects are more difficult to interpret because SCRs to CS+ remained elevated throughout extinction in the Partial Reinforced group. However, the two groups did not differ at spontaneous recovery, in terms of skin conductance or US-expectancies, primarily due to no change in the Partial Reinforced group versus increased fear responding in the Control group from the end of Extinction to test of Spontaneous Recovery. Importantly, the two groups did not differ in their rate of fear reduction from the end of acquisition to the spontaneous recovery test with participants across both groups demonstrating a significant decrease in US-expectancy ratings and skin conductance responses from the last trial of acquisition to the spontaneous recovery test. In other words, while the Partial Reinforced group showed no measurable extinction from the start to the end of extinction training, their fear responding one week later was comparable to the Control group who showed the usual extinction effects during training. Of course, the observed effects in the Partial Reinforced group are not those of spontaneous recovery since they did not show extinction from which to recover. However, some degree of long term extinction learning apparently occurred in the PR group, given their significantly lessened conditional fear responding at spontaneous recovery compared with the end of acquisition training.

The current findings seem to be consistent with the literature on gradual extinction (Gershman, Jones, Norman, Monfils, & Niv, 2013; Shiban, Wittmann, Weißinger, & Muhlberger, 2015). In such procedures, the frequency of the aversive stimuli is gradually reduced during extinction rather than abruptly eliminated. When USs are abruptly eliminated in standard extinction procedures, large prediction errors occur. According to Gershman, Blei, and Niv (2010), such large prediction errors cause a new CS-no US memory to be formed in a novel state (i.e., context) that is specific to extinction. Thus, the original CS-US fear memory remains intact and presumably predicts behavior in all contexts other than the extinction context. Gershman and colleagues believe that modifying the original CS-US memory is imperative during extinction and, in order to do so, they suggest making prediction errors during extinction small or infrequent enough to prevent formation of a new CS-no US memory but large enough to drive learning and thereby modify the original CS-US fear memory. Gershman et al. (2013) hypothesize that the gradual extinction paradigm is a way of doing so. Across two experiments, their results indicate that gradual extinction attenuates spontaneous recovery and reinstatement compared with standard extinction procedures. Shiban et al. (2015) extended these findings to humans demonstrating that, following fear conditioning procedures, gradual extinction attenuated reinstatement as measured by startle response.

Of note, Gershman and colleagues report that fear responding during extinction is no different between the gradual versus regular extinction groups during the first four trials of extinction or the last four trials of extinction. However, of the 24 extinction trials, rats in the gradual extinction procedure received CS-US pairings during trials 1, 3, 6, 10, and 15. Thus, it is conceivable that fear responding was not equivalent in the two groups in the middle of extinction (i.e., that rats in the gradual extinction group demonstrated higher levels of fear during extinction than rats in the standard extinction group). In fact, when presented with the CS 24 h after extinction, rats in the gradual extinction group demonstrated significantly higher levels of freezing (i.e., fear) than rats in the standard extinction group. However, at the spontaneous recovery test one month later, rats in the gradual extinction group demonstrated significantly lower levels of fear responding to the CS. This is very consistent with the current findings in that participants in the Partial Reinforced group demonstrated higher levels of fear

responding during extinction and yet attenuated fear recovery effects one week later as demonstrated by the rapid reacquisition test. This finding of more robust extinction learning at test despite weakened extinction performance during training in the Partial Reinforced group corresponds with other evidence that performance during extinction is a poor predictor of extinction learning at retest (Drew, Yang, Ohyama, & Balsam, 2004; Haselgrove & Pearce, 2003; Plendl & Wotjak, 2010; Prenoveau, Craske, Liao, & Ornitz, 2013; Rescorla, 2006). In fact, elevated fear responding during extinction may actually indicate greater extinction learning (e.g., Culver, Vervliet, & Craske, 2014; Rescorla, 2006).

Rapid reacquisition is especially problematic in the treatment of anxiety in which the feared catastrophe (US) is likely to reoccur following successful treatment. For example, in social anxiety treatment, typical procedures involve repeated exposure to the conditional stimuli (social situations) in the absence of the unconditional stimulus (social rejection or negative evaluation). However, occasional negative evaluations and social rejection are unavoidable in daily life. Thus, socially anxious individuals who successfully undergo exposure treatment and are subsequently faced with rejection or negative evaluation (the CS and US occur together again) are vulnerable to rapid reacquisition of social anxiety. The current results suggest that inclusion of some pairings of social situations with rejection/negative evaluation during exposure may protect against this potential for relapse. Similarly, for individuals with panic disorder, the feared catastrophe (US) is the panic attack. Exposure therapy for panic disorder involves repeated exposure to internal and external cues of panic attacks (CSs) in the absence of a panic attack, allowing individuals to learn they can experience a panic attack cue (e.g., a slight increase in heart rate) without experiencing a panic attack. However, rapid reacquisition predicts that fear responding to these cues will recover quickly if the individual again experiences a panic attack following successful therapy. Purposely inducing occasional panic attacks during exposure may protect against relapse.

There are limitations to utilizing these procedures in the clinical treatment of anxiety disorders as it may not always be ethical or feasible to incorporate CS-US pairings (e.g., when the US is a trauma in the case of post-traumatic stress disorder or when the US is an animal bite or plane crash in the case of specific phobias). However, when treating anxiety disorders in which the US is likely to reoccur following treatment and it is ethical as well as feasible to include some CS-US pairings during exposure, doing so may protect against future relapse.

Acknowledgments

This research was partially supported by a National Science Foundation Graduate Research Fellowship awarded to Najwa Culver.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jbtep.2017.07.003.

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