Behaviour Research and Therapy 125 (2020) 103535

Contents lists available at ScienceDirect

Behaviour Research and Therapy

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

Generalization of extinction of a generalization stimulus in fear learning

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ARTICLE INFO

Keywords:
Fear conditioning
Generalization
Extinction
Trait anxiety
Ambiguity

ABSTRACT

Two experiments examined whether extinction of a generalization stimulus (GS) after single cue fear conditioning would in turn generalize to other stimuli, relative to a control group that received regular extinction of CS + itself. We found only a weak effect of such "generalization of GS extinction" either back to CS + or to a different GS, on either US expectancy or skin conductance measures. In other words, despite extinction trials with a stimulus highly similar to CS+, participants showed a return of fear when tested with CS + or a novel GS. However this responding declined rapidly over non-reinforced test trials. Trait anxious participants showed higher overall US expectancy ratings in the extinction and test phases, and slower extinction of expectancy, relative to low anxious participants. These results may help explain why exposure therapy, which is unlikely to reproduce the exact stimuli present at acquisition, sometimes fails to transfer to other fear-eliciting stimuli subsequently encountered by anxious clients. The generalization of GS extinction paradigm might provide a useful testbed for evaluation of interventions designed to enhance transfer, such as exposure to multiple diverse exemplars.

1. Introduction

Fear extinction refers to a procedure in which a conditioned stimulus (CS+) that previously predicted an aversive unconditioned stimulus (US) no longer does so. As a result, conditioned fear to the CS + gradually decreases across the no-US extinction trials. Although it is intuitive to hypothesize that conditioned fear is unlearnt during extinction, empirical evidence has suggested that the original CS-US association remains intact. For example, after successful extinction, a return of conditioned fear can be triggered by a change of context (i.e., contextual renewal; Alvarez, Johnson, & Grillon, 2007; Vansteenwegen et al., 2007), the presentation of the US alone (i.e., reinstatement; Genheimer, Andreatta, Asan, & Pauli, 2017; Hermans et al., 2005), or even by the mere passage of time (i.e., spontaneous recovery; Pavlov, 1927; Huff, Hernandez, Blanding, & LaBar, 2009). Collectively, evidence like this suggests that extinction involves the formation of a new CS-no US association (Bouton, 2002). This newly formed inhibitory association competes with the original CS-US association when the extinguished CS+ is presented. Conditioned fear returns when the inhibitory extinction memory fails to compete for expression.

The fear extinction procedure has been proposed to be a valid laboratory model for exposure-based treatments for fear and anxiety disorders (Scheveneels, Boddez, Vervliet, & Hermans, 2016). It has been widely used to study the association between clinical anxiety and extinction learning, to further our understanding of the process underlying extinction in anxiety and improve the effectiveness of exposure-based therapies. Empirical studies have been carried out to examine how clinically anxious patients differ from controls in fear extinction. After differential conditioning to a threat cue (CS+) and a safety cue (CS-), anxious patients have been found to show resistance to fear extinction in both physiological responses (Blechert, Michael, Vriends, Margraf, & Wilhelm, 2007; Hermann, Ziegler, Birbaumer, & Flor, 2002; Orr et al., 2000; Peri, Ben-Shakhar, Orr, & Shalev, 2000) and self-reported valance ratings (Blechert et al., 2007; Michael, Blechert, Vriends, Margraf, & Wilhelm, 2007). These studies suggest that anxious patients may have a deficit in inhibitory learning (Davis, Falls, & Gewirtz, 2000).

More recently, research has also examined how trait anxious participants differ from controls in fear extinction. Trait anxiety is a stable personality characteristic that is widely accepted as a vulnerability factor for the development of anxiety disorders (Chambers, Power, & Durham, 2004; Gershuny & Sher, 1998; Jorm et al., 2000). One advantage of examining trait anxious samples is that they are generally free from diagnostic comorbidity, which is commonly seen in clinical samples. Indeed, many longitudinal studies have shown that trait anxiety predicts the future onset of anxiety disorders in individuals with no diagnosis at the time trait anxiety is assessed (e.g., Brown, 2007; Clark, Watson, & Mineka, 1994; La Greca, Silverman, & Wasserstein,

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https://doi.org/10.1016/j.brat.2019.103535
Received 9 April 2019; Received in revised form 5 December 2019; Accepted 17 December 2019
Available online 20 December 2019
0005-7967/

1998; Weems et al., 2007). Furthermore, using trait anxious samples addresses the question of whether impaired extinction learning is a consequence of anxiety disorder or a vulnerability marker for developing anxiety disorders. Similar to the clinical findings, trait anxious individuals show significantly slower extinction learning in skin conductance responses (Gazendam, Kamphuis, & Kindt, 2013) and US expectancy ratings (Dibbets, van den Broek, & Evers, 2015). Individuals high in intolerance of uncertainty (IU), which is also considered a vulnerability factor for developing anxiety disorders (Boelen & Reijntjes, 2009; Dugas, Gagnon, Ladouceur, & Freeston, 1998; Fetzner, Horswill, Boelen, & Carleton, 2013), show a similar pattern in extinction learning (Morriss, Christakou, & van Reekum, 2016).

Traditionally, fear extinction studies involve non-reinforced presentations of the originally trained CS+. In exposure-based therapies, however, it is very unlikely that the exact circumstances and stimuli of acquisition can be reproduced. For example, it is highly unlikely that a therapist could present the original perpetrator to a rape victim in exposure-based therapy. Technically speaking, therefore, the stimuli presented to a client during exposure therapy are generalization stimuli (GSs) that are perceptually or conceptually related to the original threat cue. In light of this issue, a small number of laboratory studies have investigated how effectively extinction learning to a GS generalizes back to the CS+. To distinguish this effect from generalization of CS + extinction (where a GS is tested after CS + extinction), we will refer to it as "generalization of GS extinction".

An example of the use of this design is the study reported by Vervliet, Vansteenwegen, Baeyens, Hermans, and Eelen (2005), who trained participants to respond differentially to a CS+ (e.g., a triangle) and a CS- (e.g., a parallelogram). In the following extinction phase, one group of participants was presented with a stimulus perceptually similar to CS+ (i.e., GS+; a perceptually different triangle) and a stimulus perceptually similar to CS- (i.e., GS-; a perceptually different parallelogram), while another group of participants was presented with the original CSs. In the subsequent test phase, participants' responding to the original CSs was assessed. The group that received CSs in extinction showed non-differential conditioned skin conductance responses and retrospective expectancy ratings to the CSs at the end of extinction, which continued in test. By contrast, the group that received GSs in extinction showed significant differential responding to the CSs in test on both measures. These results suggest that extinction with GSs is less effective than standard fear extinction in terms of inhibiting conditioned fear to the CS+. Subsequent studies have also found heightened responding to CS+ in test after GS extinction, supporting the notion that presenting a GS in extinction does not effectively generalize to the original CS+ (e.g., Barry, Griffth, Vervliet & Hermans, 2016a; Vervliet & Geens, 2014; Zbozinek & Craske, 2018).

In contrast, extinction learning to the CS + itself has been found to be effective in reducing responding to a novel GS. Vervliet, Vansteenwegen, and Eelen (2004) presented a novel GS in test after standard extinction with the CS+. Participants showed a low level of fear responding to the GS in test, indicating that extinction learning to a CS + effectively generalizes to similar novel stimuli. Similar findings have been reported by subsequent studies (Barry et al., 2016a; Barry, Vervliet, & Hermans, 2016b; Vervoort, Vervliet, Bennett, & Baeyens, 2014). In summary, previous results suggest that extinction of the CS + generalizes to a GS, whereas extinction of a GS does not generalize strongly to the CS+. In other words, generalization of CS + extinction is stronger than generalization of GS extinction.

According to many associative accounts, every stimulus can be thought to consist of numerous hypothetical perceptual elements (e.g., Blough, 1975; McLaren & Mackintosh, 2002). The more physically similar the stimuli are to one another, the more common elements they share. This means that a GS similar to the CS + would share a considerable number of elements with CS+, and these common elements would gain inhibitory strength when the GS is presented without the US in extinction. However, the remaining elements of CS + that are not shared with the GS would retain their excitatory strength. Therefore, non-reinforced presentation of the GS fails to extinguish responding to CS + completely because of these unextinguished elements uniquely possessed by the CS+. Theoretically, increasing the perceptual similarity between CS+ and GS would result in more shared elements between the two stimuli. Therefore, more common elements lose their excitatory strength during extinction, leaving fewer elements in the CS + that retain excitatory strength, resulting in a stronger generalization of GS extinction effect.

A causal judgment study by Vervliet, Vansteenwegen, and Eelen (2006) provides some supportive evidence for the above prediction. After acquiring differential conditioned responses to CS+ and CS-, one group of participants received standard CS + extinction, while the other four groups received a GS in extinction. The perceptual similarity between CS+ and GS was manipulated across these four groups. In the final test phase, all groups were presented with the CSs. Participants who received a GS most similar to CS+ in extinction showed similar expectancy ratings to the group that received the CS+ in extinction, while the other 3 groups showed significantly higher expectancies to the stimuli in test. The results suggest that using a GS highly similar to CS+ is able to produce a strong generalization of GS extinction effect.

Given the suggestive evidence by Vervliet et al. (2006), generalization of extinction with a GS highly similar to CS + warrants further investigation in a fear learning paradigm. We used stimuli on a blue-green color dimension that were highly similar to each other, but which we knew from previous research were discriminable (Lee, Hayes, & Lovibond, 2018). We conducted two experiments to investigate whether generalization of GS extinction could be demonstrated in fear conditioning using these highly similar stimuli. Additionally, we sought to examine the effect of trait anxiety on the generalization of GS extinction effect. We hypothesised that trait anxious participants would show a bias towards greater threat appraisal in the test phase (less generalization of GS extinction), due to the ambiguous threat level of test stimuli (Beckers, Krypotos, Boddez, Effting, & Kindt, 2013; Lissek, Pine, & Grillon, 2006; Wong & Lovibond, 2018; Wong & Lovibond, under review). Furthermore, we predicted that trait anxious participants would show resistance to fear extinction (Dibbets et al., 2015; Gazendam et al., 2013).

2. Experiment 1

This experiment examined whether extinction learning to a GS can effectively generalize to the original CS+. It followed Vansteenwegen et al.'s (2007) study in comparing ABA and AAA conditions. Although this terminology is usually used in context renewal studies where different letters stand for different contexts (Bouton & Bolles, 1979; Bouton & King, 1983), the context remained constant in the current experiment. Instead, each letter represented a stimulus, where A stood for CS+ and B stood for the GS. This means that both conditions were presented with the CS+ during acquisition and in test, but the ABA condition received a GS during extinction while the AAA control condition received standard extinction with the CS+. Unlike previous studies (e.g., Vervliet et al., 2005, 2006; Vervliet & Geens, 2014; Barry et al., 2016a; Zbozinek & Craske, 2018), the current experiment used a single-cue conditioning procedure instead of a differential conditioning procedure, for two reasons. First, if a perceptually similar CS- was included, a reduction in conditioned fear to CS+ in test could be attributed to the inhibitory strength of the shared elements between CS+ and CS-, or to the extinguished excitatory elements shared between the GS and CS+, or a combination of both. It is difficult to unravel these effects contributing to the reduction of conditioned fear to the CS+. Therefore, a CS- was not included in order to solely focus on the effect of extinction learning to GS on the conditioned fear to CS+. Secondly, the presence of a CS- may increase the opportunity for rule formation, potentially decreasing the ambiguity of the experimental configuration (see Lee et al., 2018; Wong & Lovibond, 2017) and reducing the

opportunity to observe an effect of trait anxiety.

3. Method

3.1. Participants

Undergraduate students were recruited as participants who received either course credit or AUD $10 for participation. Non-color blind participants were pre-screened by the DASS-21 (Lovibond & Lovibond, 1995a; 1995b), a short version of the original DASS (Depression Anxiety Stress Scales), designed to measure three constructs: depression, anxiety and stress/tension. Both the DASS and the DASS-21 have been shown to have good psychometric properties (Antony, Bieling, Cox, Enns, & Swinson, 1998; Brown, Chorpita, Korotitsch, & Barlow, 1997; Henry & Crawford, 2005; Lovibond, 1998). Participants with a DASS anxiety score of 14 or above were assigned to the high anxious (HA) group, while those with a DASS anxiety score of 4 or below were assigned to the low anxious (LA) group. Participants were re-administered the DASS-21 at the time of testing, and only those whose DASS anxiety scores remained consistent with the recruitment criteria were included. Thirty participants were recruited in each group (across anxiety and conditions), resulting in a total of 120 participants. Twenty participants were excluded (see Results). The final sample comprised 100 participants (74 females) with a mean age of 19.5 (SD = 2.6).

3.2. Apparatus and materials

Participants were tested individually in an experimental room. A 64-cm computer monitor was used to present the experimental instructions and stimuli. A computer controlled ADInstruments equipment to record the skin conductance data via GRASS® silver disc electrodes at a sampling rate of 1000 Hz throughout the experiment. Skin conductance was measured in microsiemens (μS). Another computer equipped with Matlab software (with Psychophysics Toolbox extensions; Brainard, 1997; The MathWorks Inc., 2014) was located outside the experimental room, and generated the experimental instructions and stimuli, and recorded the expectancy ratings.

Two circle stimuli with a radius of 5.75 cm (A and B) were used in the current experiment (Fig. 1). Both stimuli lay on a blue-green dimension, varying in their hue. Stimulus A was an aqua color circle with a hue of 0.479 (hue saturation value model), and stimulus B was a slightly greener circle with a hue of 0.446. The saturation and brightness for both stimuli were held constant at 1 and 0.75 respectively. Stimulus A served as the CS+ and stimulus B served as the GS. Note that the colors for CS+ and CS- were not counterbalanced, since the stimulus dimension has produced symmetrical generalization gradients in our previous work (see Lee et al., 2018; Wong & Lovibond, 2017). All stimuli were presented in the centre of a grey background (RGB value = [200 200 200]) on the computer screen.

Skin conductance electrodes filled with isotonic gel were attached to the distal and proximal segments of the third finger of participants' non-dominant hand. The electrical US was a 0.5-s sinusoidal pulse electric stimulation (80 Hz) delivered through two stainless steel electrodes attached to the distal and middle segments of the index finger of the same hand. A semi-circular dial with a rotary pointer was attached to the table in front of the participants. The dial ranged from 0% (labelled *Certain NO SHOCK*) to 100% (labelled *Certain SHOCK*).

Table 1
Design of experiment 1.

Condition	Acquisition	Extinction	Test
ABA	A+ (6)	B- (8)	A- (3)
AAA	A- (2)	A- (8)	

Note. + indicates electrical US presentation; - indicates electrical US omission; numbers in brackets indicate the number of trials of that type in each phase.

3.3. Procedure

After the electrical US electrodes were attached, participants were led through a work-up procedure in which they selected a level of US intensity that was 'definitely uncomfortable but not painful'. Skin conductance electrodes were then attached and participants were taken into the experimental room. As shown in Table 1, the experiment consisted of an acquisition phase, followed by an extinction phase and a test phase. Before the experiment started, headphones were placed on participants. White noise was presented continuously throughout the experiment for noise cancellation.

Acquisition. Participants were informed that some circles would be presented on the screen, which may or may not be followed by an electrical US. They were asked to learn the relationship between the circles and electrical US. Participants were then instructed to use the expectancy dial to indicate their expectancy of electrical US whenever a circle appeared.

Both ABA and AAA conditions received 8 trials of stimulus A presentations, in which 6 trials were reinforced (i.e., 75% reinforcement). Stimulus A was not fully reinforced for two reasons. First, extinction learning in humans occurs rapidly. Partial reinforcement of A+ slows down extinction (Mackintosh, 1974) and allows room to examine the effect of trait anxiety on fear extinction. Second, partial reinforcement is thought to increase the ambiguity of the experimental task, again increasing the opportunity to observe any trait anxiety effects (Beckers et al., 2013; Lissek et al., 2006). The presentation order was pseudo-randomized, so that the first and last trials were always reinforced, and non-reinforced A trials did not occur twice in a row. The trial structure consisted of a 10-s baseline period, a 10-s stimulus presentation, and an ITI period that varied between 10 and 21s. Electrical US, if presented, was delivered in the last 0.5-s of A+ trials and co-terminated with the stimulus.

Extinction. In this phase, participants in the AAA condition received 8 trials of A- presentations, while those in the ABA condition received 8 trials of B- presentations. All stimulus presentations in this stage were non-reinforced. The trial structure was identical to acquisition, with the exception that no electrical US was delivered at all.

Test. Participants in both the ABA and AAA conditions received 3 trials of A- presentations. This phase was to assess how extinction of the training stimulus (AAA) and extinction with a novel stimulus (ABA)

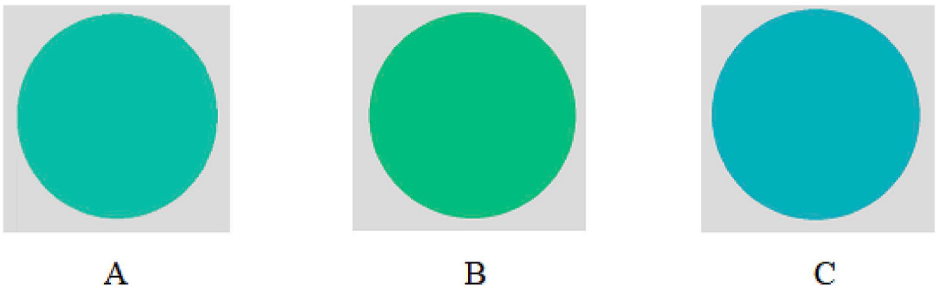

Fig. 1. Stimuli used in the two experiments. In Experiment 1, stimulus A served as CS + for both the AAA and ABA conditions. Stimulus B served as the GS presented in extinction in the ABA condition. In Experiment 2 the same stimuli were used in acquisition and extinction, but stimulus C served as the novel GS presented in test in both the AAC and ABC conditions. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

would affect fear responding to A. The trial structure was identical to the previous extinction phase.

When the conditioning task was finished, participants were asked to fill in a questionnaire. They were asked how many different colors were presented in the task, and were asked to name or describe the colors they saw. Given that the stimuli used in the current experiment were highly similar, this questionnaire served as a vital check for whether participants in the ABA condition were able to distinguish between stimuli A and B, or if participants in the AAA condition had a misperception that more than one color was presented. For instance, if a participant in the ABA condition failed to distinguish between stimuli A and B, any effect on responding to A in test could be attributed to standard extinction (an AAA effect) rather than a genuine effect of generalization of GS extinction (an ABA effect).

3.4. Scoring and analysis

A low-pass digital filter was applied to cut off any skin conductance activity higher than 50 Hz, in order to avoid aliasing. The raw skin conductance data were then log transformed to minimise individual differences. Skin conductance scores for each trial were calculated as the difference between the log of mean skin conductance level (SCL) during the 10-s stimulus presentation and log mean SCL during the 10-s baseline period for that trial.

Planned contrasts were used to compare the two group factors – Conditions (AAA vs ABA) and Anxiety (HA vs LA) – across acquisition, extinction and test. Data from all three phases were analysed with a linear trend repeated measures contrast. Interactions between all group and repeated measures contrasts were tested to evaluate group differences in linear trend in each phase. Three additional contrasts were included to assess cross-phase effects. We were primarily interested in the interactions between these contrasts and conditions, which allowed us to compare the magnitude of cross-phase effects in the two conditions. Comparison between the last acquisition trial and the first extinction trial tested the impact of changing from the CS + to the GS in the ABA condition, relative to the AAA condition. Comparison between the last extinction trial and the first test trial tested the impact of shifting from the GS back to the CS+ in the ABA condition, relative to the AAA condition. Finally, comparison of the last acquisition trial and the first test trial tested the impact of having extinguished a GS in the ABA condition, relative to standard extinction in the AAA condition. Interactions with Anxiety were also tested in these cross-phase analyses (see Table 2 for a summary of the primary comparisons of interest).

4. Results

Only participants who satisfied the acquisition criterion, that is, expectancy ratings to A+ more than 50 averaged over the last 4 acquisition trials, were included in statistical analyses. Six participants were excluded based on this criterion. Additionally, 8 participants in the ABA condition were excluded because they either reported there was only one color or more than two colors presented throughout the experiment. Five participants in the AAA condition reported seeing more than one color in the experiment, and hence were excluded. Furthermore, 1 participant in the AAA condition was excluded due to not giving expectancy ratings for more than 2 trials in the extinction and test phases. Altogether, 20 participants were excluded, leaving 100 participants in the final sample.

4.1. Demographic data

The mean DASS anxiety scores were 14.8 and 3.8 for the HA and LA groups respectively. There were no significant differences in sex distribution between groups or conditions (highest $\chi 2$ [2] = 1.9, p = 0.17), nor any differences in age between groups or conditions (highest F = 2.2, p = 0.14). More importantly, the mean US intensities for both groups were 2.5, indicating no anxiety difference in the tolerance of electrical US, $F(1,98)$ = 0.001, p = 0.98, η_p^2 < 0.01.

4.2. Acquisition

Fig. 2A shows the mean US expectancy ratings during acquisition. Expectancy ratings to A+ increased rapidly, dropped slightly, and then levelled off for the remaining acquisition trials with asymptotic ratings at approximately the reinforcement rate of 75%. The increase followed by drop-off in expectancy ratings may have been due to the fact that the first CS + trial was always reinforced. Acquisition was supported by a significant main effect of linear trend across trials, $F(1,96)$ = 53.4, p < 0.01, η_p^2 = 0.36. No main effect involving anxiety or condition (ABA vs AAA) was significant, nor the interaction between anxiety and condition (highest F = 0.4, p = 0.53, η_p^2 < 0.01). Unexpectedly, participants in the ABA condition showed a slightly steeper decrease in expectancy ratings to CS + after reaching peak than those in the AAA condition. This resulted in a relatively steeper linear trend in the AAA condition, confirmed by a significant interaction between condition and linear trend, $F(1,96)$ = 6.1, p = 0.02, η_p^2 = 0.06. This effect further interacted with anxiety, where the drop-off in expectancy ratings in the ABA conditions was more pronounced in the HA group, while LA participants showed similar acquisition trends in both conditions, $F(1,96)$ = 11.9, p < 0.01, η_p^2 = 0.11. However, it was impossible for

Table 2
The comparisons of interests in Experiment 1.

Phases	Contrasts	Interpretations
Acquisition/Extinction/Test	Anxiety	Comparison of HA vs LA groups averaged across conditions and trials in each phase
	Condition	Comparison of AAA vs ABA averaged across anxiety groups and trials in each phase
	Linear trend	Within group contrast to assess any linear increases or decreases across trials in each phase (e.g., acquisition, extinction)
	Condition*Linear	The effect of condition on acquisition or extinction in each phase
	Anxiety*Linear	The effect of anxiety on acquisition or extinction in each phase
	Anxiety*Condition*Linear	The effect of condition on acquisition or extinction modulated by anxiety in each phase
Cross-phase comparisons		
Last Acquisition trial and first Extinction trial (ACQvEXT)	Condition*ACQvEXT	The impact of changing from the CS + to the GS in the ABA condition relative to the AAA condition (i.e., generalization decrement)
	Anxiety*Condition* ACQvEXT	The effect of anxiety on generalization decrement
Last Extinction trial and first Test trial (EXTvTEST)	Condition*EXTvTEST	The impact of stimulus type in extinction (CS or GS) on responding to the test stimulus (i.e., return of fear)
	Anxiety*Condition* EXTvTEST	The effect of trait anxiety on return of fear
Last Acquisition trial and first Test trial (ACQvTEST)	Condition*ACQvTEST	The impact of stimulus type in extinction (CS or GS) on responding to the test stimulus (i.e., generalization of GS extinction)
	Anxiety*Condition* ACQvTEST	The effect of trait anxiety on generalization of GS extinction

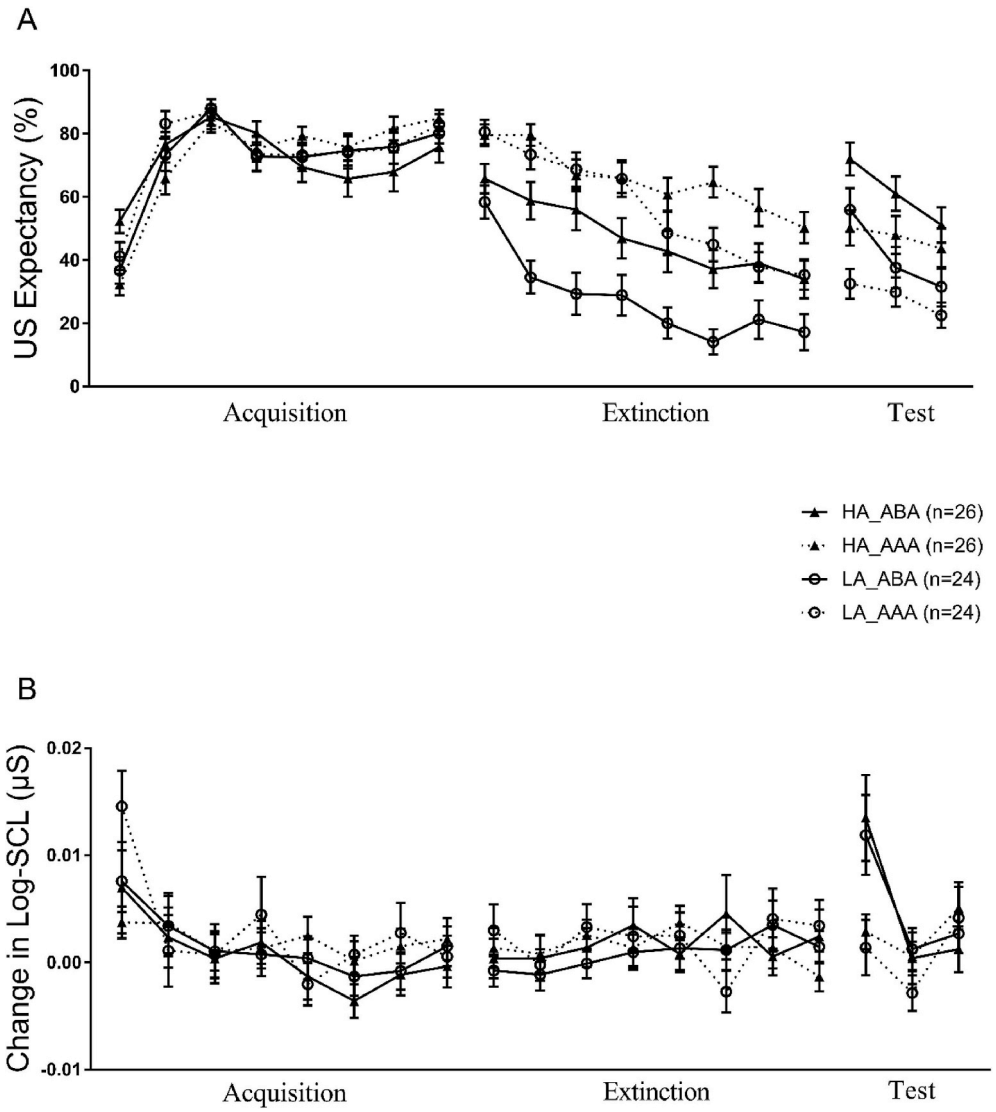

Fig. 2. Mean US expectancy ratings (Top panel) and skin conductance level (SCL; Bottom panel) across acquisition, extinction and test trials in Experiment 1. HA = High Anxious; LA = Low Anxious; ABA = ABA condition; AAA = AAA condition.

condition to affect acquisition to the training stimulus systematically since the acquisition phases in both conditions were identical. Therefore, this interaction appears to be a Type I error. Trait anxiety per se had no effect on fear learning across the Acquisition phase, $F(1,96) = 0.0001$, $p = 0.99$, $\eta_p^2 < 0.01$.

Fig. 2B shows the mean change in log SCL during acquisition. Across anxiety groups and conditions, participants showed a steady decrease in skin conductance responding to CS+, confirmed by a significant main effect of linear trend across trials, $F(1,96) = 18.0$, $p < 0.01$, $\eta_p^2 = 0.17$. The skin conductance data did not directly align with the expectancy data, as the level of responding to CS + decreased across trials. This pattern is common in skin conductance studies, and is generally attributed to habituation to the CS and US across trials. Habituation is often controlled for by inclusion of a non-reinforced stimulus (differential conditioning design), but as mentioned earlier this design was not appropriate for the present experiment. No effects of anxiety and condition, nor the interactions involving these factors, were found to significantly affect skin conductance during acquisition (highest F = 1.9, $p = 0.17$, $\eta_p^2 < 0.01$).

4.3. Extinction

All groups showed a decrease in their mean expectancy ratings to the extinction stimulus (Fig. 2A), supported by a significant main effect of linear trend, $F(1,96) = 184.2$, $p < 0.01$, $\eta_p^2 = 0.66$. HA participants had higher expectancy ratings to the extinction stimulus than LA participants averaged across conditions and trials, resulting in a significant main effect of anxiety, $F(1,96) = 10.1$, $p < 0.01$, $\eta_p^2 = 0.10$. Averaged across anxiety groups and trials, participants in the AAA condition had higher expectancy ratings than participants in the ABA condition, confirmed by a significant main effect of condition, $F(1,96) = 27.9$, $p < 0.01$, $\eta_p^2 = 0.23$. The interaction between anxiety and condition did not reach significance, $F(1,96) = 1.5$, $p = 0.22$, $\eta_p^2 = 0.01$. Averaged over conditions, HA participants showed less decrease in US expectancies across trials than their LA counterparts, confirmed by a significant interaction between anxiety and linear trend, $F(1,96) = 5.3$, $p = 0.02$, $\eta_p^2 = 0.05$. This suggests that HA participants showed slower overall extinction than their LA counterparts. Condition itself had no reliable effect on the rate of extinction, $F(1,96) = 1.0$, $p = 0.32$, $\eta_p^2 = 0.01$. The effect of anxiety on linear trend was somewhat more pronounced in the AAA condition than in the ABA condition. That is, the effect of trait anxiety on fear extinction was mostly driven by the

AAA condition, whereas the linear trends for the HA and LA groups in the ABA condition were similar. However, this three-way interaction did not reach significance, $F(1,96) = 3.5$, $p = 0.06$, $\eta_p^2 = 0.04$.

Unlike the expectancy measure, the skin conductance data displayed an irregular pattern (Fig. 2B), showing no reliable extinction effect across anxiety groups and conditions, $F(1,96) = 1.4$, $p = 0.24$, $\eta_p^2 < 0.01$. No main effects regarding anxiety or conditions, nor any interactions involving linear trend, were significant (highest F = 2.6, $p = 0.11$, $\eta_p^2 = 0.01$).

4.4. Test

Averaged across anxiety groups and conditions, participants showed a decrease in expectancy ratings to the CS + across the 3 test trials (Fig. 2A), confirmed by a significant main effect for linear trend, $F(1,96) = 52.4$, $p < 0.01$, $\eta_p^2 = 0.35$. Averaged across anxiety groups and test trials, the ABA condition showed higher expectancy ratings to the test stimulus than those in the AAA condition, confirmed by a significant main effect of condition, $F(1,96) = 6.8$, $p = 0.01$, $\eta_p^2 = 0.07$. HA participants showed higher expectancy ratings to the test stimulus than LA participants averaged across conditions and trials, supported by a significant main effect of anxiety, $F(1,96) = 13.5$, $p < 0.01$, $\eta_p^2 = 0.12$. The ABA condition showed a significantly faster decrease in expectancy ratings across the test trials than the AAA condition, resulting in a significant interaction between condition and linear trend, $F(1,96) = 11.4$, $p < 0.01$, $\eta_p^2 = 0.11$. That is, participants who had been presented with a GS in extinction showed a faster decline in responding to the CS+ in test. No other interactions reached significance (highest F = 0.7, $p = 0.40$, $\eta_p^2 < 0.01$).

Similar to the expectancy measure, participants showed an overall decrease in skin conductance responding to the test stimulus across test trials averaged over anxiety groups and conditions (Fig. 2B), confirmed by a significant linear trend over the test trials, $F(1,96) = 5.3$, $p = 0.02$, $\eta_p^2 = 0.06$. Averaged across anxiety groups, the ABA condition had higher fear responding to the test stimulus than the AAA condition, but this effect did not reach significance, $F(1,96) = 3.8$, $p = 0.054$, $\eta_p^2 = 0.05$. No main effect of anxiety on responding in test was observed, $F(1,96) = 0.25$, $p = 0.6$, $\eta_p^2 < 0.01$. Similar to the expectancy measure, the ABA condition showed a more rapid decrease in responding across the test trials than those in the AAA condition, resulting in a significant interaction between condition and linear trend, $F(1,96) = 13.7$, $p < 0.01$, $\eta_p^2 = 0.12$. No other interactions reached significance (highest F = 0.4, $p = 0.53$, $\eta_p^2 < 0.01$).

4.5. Comparison between phases

Last acquisition trial vs first extinction trial. The ABA condition showed a substantial decrease in expectancy ratings in the first extinction trial relative to the last acquisition trial, while the AAA condition showed a continuity in responding between acquisition and extinction, confirmed by a significant interaction between condition and trial, $F(1,96) = 5.0$, $p = 0.03$, $\eta_p^2 = 0.05$. This decrease in expectancy ratings in the ABA condition suggests a generalization decrement from stimulus A (CS+) to B (GS). Trait anxiety did not have any reliable effect on the generalization decrement from A to B, $F(1,96) = 1.9$, $p = 0.2$, $\eta_p^2 = 0.02$. On the skin conductance measure, participants in the ABA condition did not show a reliable generalization decrement relative to the AAA condition, $F(1,96) = 0.5$, $p = 0.5$, $\eta_p^2 < 0.01$. HA participants showed a slight increase in skin conductance responding from acquisition to extinction in the ABA condition, while LA participants showed no observable differences in responding between these two trials in the same condition. Conversely, whereas HA participants in the AAA condition showed a decrease in responding from acquisition to extinction, LA participants showed an opposite pattern in the same condition. This led to a significant 3-way interaction involving anxiety groups, conditions and the comparison between acquisition and extinction, $F(1,96) = 4.2$, $p = 0.04$, $\eta_p^2 = 0.06$.

Last extinction trial vs first test trial. The ABA condition showed a large increase in expectancy ratings from extinction to test, while the AAA condition showed similar expectancy ratings to the stimuli in the transition from extinction to test. This pattern resulted in a significant interaction between condition and the comparison between the last extinction and first test trials, $F(1,96) = 35.5$, $p < 0.01$, $\eta_p^2 = 0.27$. In other words, participants who received standard extinction in the AAA condition continued to show low US expectancies to the CS+, while those who received a GS in extinction showed significantly heightened expectancy ratings when the CS+ was presented again in test. The skin conductance data showed a similar pattern, confirmed by a significant interaction between condition and trial, $F(1,96) = 8.2$, $p < 0.01$, $\eta_p^2 = 0.07$. There were no reliable effects involving trait anxiety on either measure (highest F = 0.7, $p = 0.7$, $\eta_p^2 < 0.01$).

Last acquisition trial vs first test trial. The AAA condition showed a significantly greater decrease in expectancy ratings from the last acquisition trial to the first test trial when compared to the ABA condition, $F(1,96) = 20.0$, $p < 0.01$, $\eta_p^2 = 0.17$. This finding suggests that standard extinction with the trained CS+ is more effective in reducing conditioned fear to that stimulus than extinction of a GS (i.e., weak effect of generalization of GS extinction). This interaction did not further interact with anxiety, $F(1,96) = 0.1$, $p = 0.7$, $\eta_p^2 < 0.01$. Although the ABA condition was less effective than the AAA condition in reducing fear to CS+, a simple effect comparing the last acquisition trial to the first test trial in the ABA condition alone was significant, $F(1,48) = 8.3$, $p < 0.01$, $\eta_p^2 = 0.15$, demonstrating that there was some reduction of fear from acquisition to test. Unlike the expectancy measure, participants in the ABA condition showed an increase in skin conductance responding from acquisition to test, whereas participants in the AAA condition did not change greatly, leading to a significant interaction between condition and trial, $F(1,96) = 12.7$, $p < 0.01$, $\eta_p^2 = 0.14$. This interaction did not further interact with anxiety, $F(1,96) = 0.3$, $p = 0.6$, $\eta_p^2 < 0.01$.

5. Discussion

The current experiment sought to examine whether the use of highly perceptually similar stimuli for CS+ and GS would lead to reliable generalization of GS extinction; in other words, whether extinguishing a GS that strongly resembles the CS + would reduce fear responding to CS+ in test. Another primary aim of this experiment was to examine whether trait anxiety has any effect on fear extinction, or the generalization of GS extinction.

The ABA condition showed a decrease in expectancy ratings from the last acquisition trial to the first extinction trial. This decrease suggests a generalization decrement from CS + to GS, and confirms participants' capability to distinguish between these two stimuli. The lower average threat expectancies across extinction in the ABA condition can be attributed to persistence of the generalization decrement from CS + to GS seen at the beginning of extinction. The skin conductance measure, however, showed a more complex pattern. The significant 3-way interaction involving the acquisition-extinction comparison was a relatively small effect and is difficult to interpret. Of more importance is the lack of evidence for generalization decrement on the skin conductance measure; that is, responding did not decline in the ABA condition when the GS was presented in extinction. One possible explanation for this result is a floor effect on the skin conductance measure. Another factor may have been that the novelty of the switch from CS + to GS offset any reduction in associative responding.

One of the critical findings in this experiment was that extinction with a GS (ABA condition) was substantially less effective in reducing conditioned fear to the CS itself, (AAA condition), confirmed by the significant interaction between condition and the acquisition-test comparison. Interestingly, GS extinction was still able to significantly decrease fear to the CS+ in test. However, this pattern is potentially

Table 3
Design of experiment 2.

Phase/Condition	Acquisition	Extinction	Test
ABC	A+ (6)	B- (8)	C- (3)
AAC	A- (2)	A- (8)	

Note. + indicates electrical US presentation; - indicates electrical US omission; numbers in brackets indicate the number of trials of that type in each phase.

confounded with the time between acquisition and test. Therefore, the decrease in conditioned fear in test could in part be due to the lapse of time since acquisition (see Bouton & García-Gutiérrez, 2006). However, given that the lapse of time between acquisition and test was approximately 6 min, the effect of time should be minimal. Nonetheless, complementing the aforementioned findings, we observed a high level of responding to the trained stimulus on both measures at test, in the ABA but not in the AAA condition. This means that participants who had received standard fear extinction with CS + continued to show a low level of conditioned fear to CS+ in test, while those who had received a GS in extinction showed strong responding to CS+ in test. This again suggests that GS extinction was not as effective as extinction with a CS+, as it induced a larger return of fear to CS+. This finding is consistent with previous studies that found a change in stimulus during extinction causes an increase in responding to the trained value in test (Barry et al., 2016a; Vervliet et al., 2005; Vervliet & Geens, 2014), despite our attempt to use a GS that was highly similar to (yet discriminable from) the CS+.

Interestingly, the ABA condition showed a more rapid decline in fear responding to the CS + over test trials compared to the AAA condition in both expectancy and skin conductance measures. There are two possible reasons that might account for this finding. First, participants in the ABA condition had higher US expectancies to the CS + on the first test trial when compared to the AAA condition, hence there was more room for responding to CS + to decline. Second, after experiencing a non-reinforced CS + on the first test trial, participants in the ABA condition may have rapidly formed the belief that the CS + no longer predicted an electrical US given that they had already experienced a similar exemplar that did not predict electrical US.

Regarding trait anxiety, high anxious individuals showed consistently higher US expectancies in both extinction and test than their low anxious counterparts. Furthermore, high anxious participant showed slower extinction. This is consistent with the idea that trait anxious individuals show a resistance to extinction of fear (Dibbets et al., 2015; Gazendam et al., 2013). Although this pattern was stronger in the AAA condition than in the ABA condition, suggesting that anxious individuals showed greater resistance to extinction to the original CS + than to a novel GS, this pattern did not reach significance. Furthermore, these effects were only evident in the expectancy measure but not the skin conductance measure.

5.1. Experiment 2

The second experiment sought to examine whether extinction learning to a GS can effectively generalize to another novel GS by comparing an ABC condition to an AAC control condition. In other words, the current experiment examined whether extinction of a GS (stimulus B) can generalize to a novel cue (stimulus C) that is similar to both the CS+ (stimulus A) and the extinguished GS (stimulus B). The ABC condition is more relevant to exposure therapy since it is unlikely that anxious clients will encounter the original threat cue after treatment, but they may encounter cues that differ from those used in treatment. We again investigated the effect of trait anxiety on generalization of GS extinction.

5.2. Participants

We expected that the inclusion of a further similar novel GS (stimulus C) would result in more participants not being able to distinguish between the stimuli, therefore increasing the number of excluded participants and reducing the power of statistical analysis. In light of this, we recruited a total of 12 more participants in the current experiment than in Experiment 1. Thirty-three undergraduate students were recruited in each group (anxiety groups and conditions), resulting in a total of 132 participants. The final sample after exclusions comprised 101 participants (74 females) with a mean age of 20.3 (SD = 2.8).

5.3. Apparatus and materials

All the apparatus and materials were the same as those used in Experiment 1, with the addition of stimulus C. Stimulus C lay on the same blue-green dimension as stimuli A and B (see Fig. 1). It was a slightly bluer circle than Stimulus A, with a HSV value of 0.512. The saturation and brightness for stimulus C were held the same as A and B at 1 and 0.75 respectively. The radius of stimulus C was 5.75 cm.

5.4. Procedure

The acquisition and extinction phases in the current experiment were exactly the same as Experiment 1. During test, both conditions received 3 trials of a novel GS (stimulus C) without any reinforcement (see Table 3).

6. Results and discussion

Exclusion criteria were identical to Experiment 1. Five participants were excluded because they did not meet the acquisition criterion. Fifteen participants in the ABC condition were excluded because they failed to report seeing exactly 3 different colors in the post-experimental questionnaire. Similarly, 8 participants in the AAC condition failed to correctly report seeing 2 colors. In addition, 3 participants were excluded because their skin conductance was not measured properly due to technical problems. Altogether, 31 participants were excluded, leaving 101 participants in the final sample. We conducted a planned contrast analysis identical to Experiment 1 (see Table 2).

6.1. Demographic data

The mean DASS anxiety scores were 15.8 and 3.9 for the HA and LA groups respectively. There were no differences in sex distribution between groups or conditions highest $\chi 2$ [2] = 1.4, p = 0.24), nor any age differences between groups or conditions (highest F = 1.7, p = 0.20). More importantly, the mean US intensities for the HA and LA group were 2.2 mA and 2.3 mA respectively, and there was no evidence that there was any anxiety difference in the tolerance of electrical US, F (1,97) = 0.3, p = 0.59, η_p^2 < 0.01.

6.2. Acquisition

Fig. 3A shows the mean US expectancy ratings during acquisition. As in Experiment 1, all groups showed a sharp increase in expectancy ratings to CS+, which then dropped off slightly to an asymptote at around 80%. This pattern was supported by a significant main effect of linear trend, F(1,97) = 61.2, p < 0.01, η_p^2 = 0.39. Unlike Experiment 1, no main effects of anxiety or condition, or interactions involving either factors and linear trend reached significance (highest F = 1.2, p = 0.28, η_p^2 = 0.01). Fig. 3B shows the mean change in log SCL during acquisition. Unlike the expectancy measure, but similar to Experiment 1, participants showed a reduction in skin conductance responding to CS + across trials, confirmed by a significant main effect of linear trend, F(1,97) = 10.0, p < 0.01, η_p^2 = 0.10. Averaged across

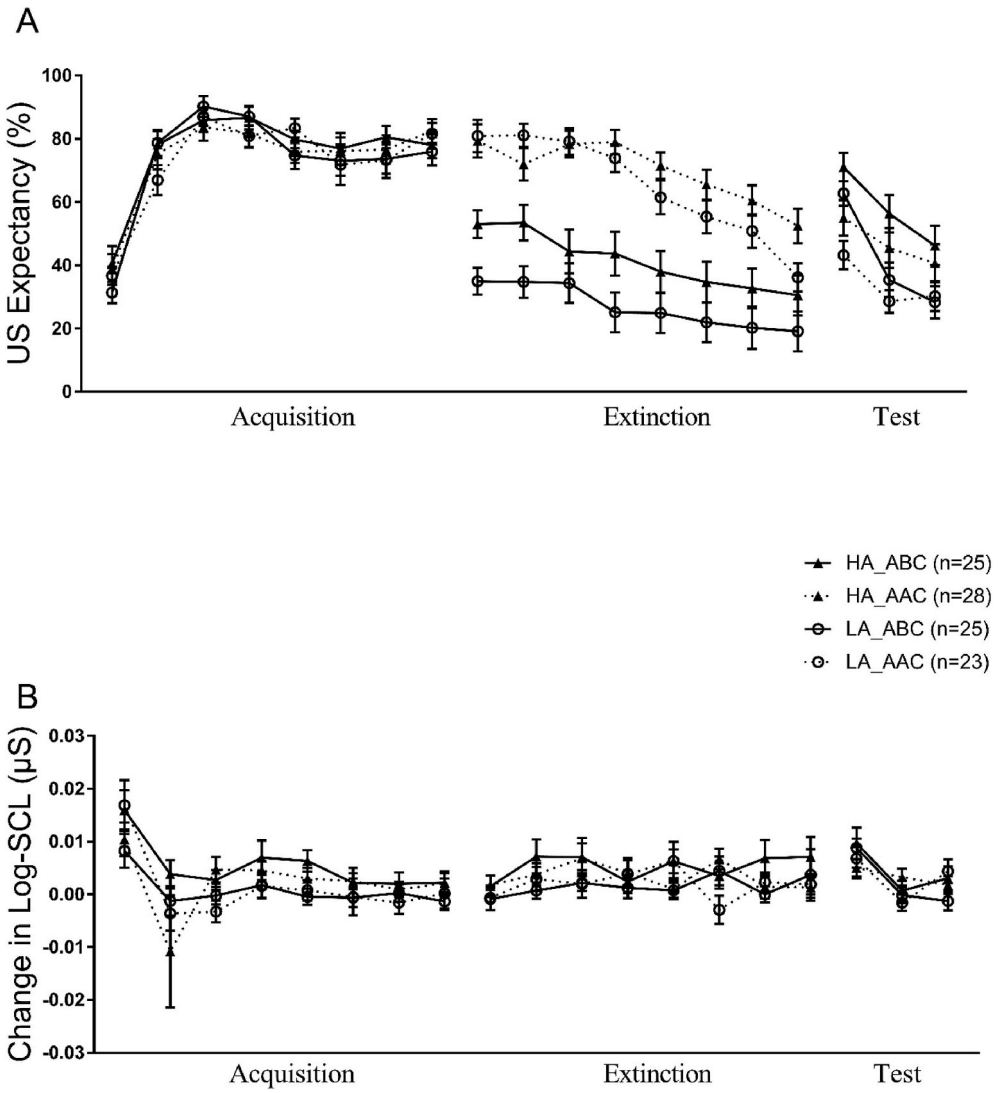

Fig. 3. Mean US expectancy ratings (Top panel) and skin conductance level (SCL; Bottom panel) across acquisition, extinction and test trials in Experiment 2. HA = High Anxious; LA = Low Anxious; ABC = ABC condition; AAC = AAC condition.

conditions and trials, responding to CS+ was somewhat higher in the HA group than in the LA group, but this difference did not reach significance, $F(1,97) = 2.5$, $p = 0.12$, $\eta_p^2 = 0.02$. No other main effects or interactions reached significance (highest F = 1.2, $p = 0.28$, $\eta_p^2 = 0.02$).

6.3. Extinction

Overall, participants showed a decrease in expectancy ratings to the extinction stimulus across trials (Fig. 3A), supported by a significant main effect of linear trend, $F(1,97) = 86.2$, $p < 0.01$, $\eta_p^2 = 0.47$. Averaged over trials, HA participants had higher expectancy ratings to the extinction stimulus than their LA counterparts, resulting in a significant main effect of anxiety, $F(1,97) = 5.3$, $p = 0.02$, $\eta_p^2 = 0.05$. Participants in the AAC condition showed significantly overall higher expectancy ratings to the extinction stimulus than those in the ABC condition, $F(1,97) = 62.6$, $p < 0.01$, $\eta_p^2 = 0.39$. This difference appears to have been due to the persistence of generalization decrement from A (CS+) to B (GS) in the ABC condition seen at the beginning of extinction. Averaged across anxiety groups, participants in the AAC condition showed a relatively faster decline in expectancies across trials, resulting in a significant interaction between condition and linear trend, $F(1,97) = 5.0$, $p = 0.03$, $\eta_p^2 = 0.05$. In other words, participants showed a slightly faster rate of extinction when presented with the CS+ (A) compared to a novel GS (B). This difference in extinction rate between conditions was more pronounced in the LA group than the HA group, leading to a 3-way interaction between anxiety, condition and linear trend, $F(1,97) = 5.2$, $p = 0.03$, $\eta_p^2 = 0.05$. No other interactions reached significance (highest F = 1.5, $p = 0.22$, $\eta_p^2 = 0.01$).

In contrast to the expectancy measure, participants showed no reliable extinction effect in skin conductance (Fig. 3B) across anxiety groups and conditions, $F(1,97) = 0.7$, $p = 0.41$, $\eta_p^2 < 0.01$. HA participants had higher overall responding across trials than the LA participants, but this difference did not reach significance, $F(1,97) = 2.8$, $p = 0.10$, $\eta_p^2 = 0.02$. No other main effects or interactions reached significance (highest F = 2.1, $p = 0.15$, $\eta_p^2 = 0.01$).

6.4. Test

All groups showed a decline in expectancy ratings across trials, supported by a main effect of linear trend, $F(1,97) = 73.3$, $p < 0.01$, $\eta_p^2 = 0.43$, in line with the test stimulus being presented without any reinforcement (Fig. 3A). Averaged across anxiety groups and trials, participants in the ABC condition showed higher expectancy ratings to the test stimulus C than those in the AAC condition, resulting in a main effect of condition, $F(1,97) = 4.2$, $p = 0.04$, $\eta_p^2 = 0.04$. HA

participants had higher expectancy ratings than LA participants to the test stimulus C averaged across conditions and trials, confirmed by a main effect of anxiety, $F(1,97) = 9.5$, $p < 0.01$, $\eta_p^2 = 0.09$. The ABC condition showed a more rapid decrease in expectancy ratings across the test trials than the AAC condition, leading to a significant interaction between condition and linear trend, $F(1,97) = 10.0$, $p < 0.01$, $\eta_p^2 = 0.09$. Thus, participants who had experienced a GS in extinction (ABC condition) showed faster extinction learning to a novel GS than those who experienced standard extinction with the original threat cue (AAC condition). No other interactions reached significance (highest $F = 1.2$, $p = 0.28$ $\eta_p^2 = 0.01$).

For skin conductance (Fig. 3B), participants showed a general decline in responding across the test trials averaged across anxiety groups and conditions, confirmed by a significant main effect of linear trend, $F(1,97) = 11.9$, $p < 0.01$, $\eta_p^2 = 0.13$. Similar to the expectancy measure, participants in the ABC condition showed a more rapid decrease in responding than those in the AAC condition, although this difference did not reach significance, $F(1,97) = 2.9$, $p = 0.09$. $\eta_p^2 = 0.04$. No other effects reached significance (highest $F = 0.43$, $p = 0.51$, $\eta_p^2 < 0.01$).

6.5. Comparison between phases

Last acquisition trial vs first extinction trial. Participants in the ABC condition had a significant drop in expectancy ratings from acquisition to extinction, while those in the AAC condition showed a continuity in expectancy ratings in the transition of the two phases. This pattern was confirmed by a significant interaction between condition and the comparison between the last acquisition and first extinction trials, $F(1,97) = 35.2$, $p < 0.01$, $\eta_p^2 = 0.27$. Thus, participants in the ABC condition showed a generalization decrement due to the change of stimulus between acquisition and extinction. This generalization decrement effect appeared to be larger among the LA participants than the HA participants - in other words, HA participants in the ABC condition showed stronger generalization from the CS + to GS than their LA counterparts in the same condition. However, this difference did not reach significance, $F(1,97) = 3.0$, $p = 0.09$, $\eta_p^2 = 0.03$. No other effects were significant (highest $F = 2.1$, $p = 0.15$, $\eta_p^2 = 0.02$). The skin conductance data did not reveal any reliable differences in responding between acquisition and extinction between conditions, nor any significant trait anxiety effects (highest $F = 2.1$, $p = 0.15$, $\eta_p^2 = 0.02$).

Last extinction trial vs first test trial. The ABC condition showed a marked increase in US expectancies from extinction to test, while the AAC condition showed similar expectancy ratings between extinction and test, leading to a significant interaction between condition and trial, $F(1,97) = 29.9$, $p < 0.01$, $\eta_p^2 = 0.24$. That is, GS extinction triggered more conditioned fear to another novel GS than standard CS extinction, suggesting that GS extinction is less effective in reducing fear to the novel test stimulus than CS extinction. This difference did not differ between anxiety groups, $F(1,97) = 0.01$, $p = 0.9$, $\eta_p^2 < 0.01$. No reliable effects were observed in skin conductance (highest $F = 0.2$, $p = 0.7$, $\eta_p^2 < 0.01$).

Last acquisition trial vs first test trial. The decrease in expectancy ratings from the last acquisition trial to the first test trial was larger in the AAC condition compared to the ABC condition, $F(1,97) = 13.1$, $p < 0.01$, $\eta_p^2 = 0.12$. However, a simple effect confirmed that participants in the ABC condition did show a significant decrease in expectancies from acquisition to test, $F(1,48) = 5.5$, $p = 0.02$, $\eta_p^2 = 0.10$. However, this effect did not further interact with anxiety, $F(1,97) = 0.1$, $p = 0.8$, $\eta_p^2 < 0.01$. For the skin conductance measure, the difference in responding between acquisition and test did not differ between conditions, nor between anxiety groups (highest $F = 1.8$, $p = 0.18$, $\eta_p^2 = 0.01$).

6.6. General discussion

In two experiments using a single-cue fear conditioning procedure, we tested several of our predictions. First, we examined whether trait anxious individuals showed slower fear extinction than their low anxious counterparts like previous findings did (e.g., Dibbets et al., 2015; Gazendam et al., 2013). Second, we tested whether using a GS highly similar to the CS in extinction would produce a stronger generalization of GS extinction effect than previous studies (Barry et al., 2016a; Vervliet et al., 2004; 2005). Third, we examined whether trait anxious individuals would show higher threat appraisal to test stimuli when compared to low anxious individuals.

As predicted, high anxious individuals showed higher US expectancies across extinction when compared to low anxious individuals. This was partly due to the persistence of a stronger fear generalization observed among anxious individuals in the ABA and ABC conditions, although this did not reach statistical significance, and partly due to resistance to extinction among anxious individuals in the AAA and AAC conditions. The finding that resistance to extinction was only observed among trait anxious individuals who received a CS+ in extinction aligns with the general finding that trait anxiety is associated with an increase in threat appraisal under threat ambiguity (e.g., Boddez et al., 2012; Chan & Lovibond, 1996; Chen & Lovibond, 2016). According to Bouton (1993, 2002), a CS+ in extinction is ambiguous because it possesses two different meanings: the CS-US association and the newly formed CS-no US association. The GS can also be considered to have additional ambiguity because of its novelty and its perceptual similarity with the threat cue. However, it did not have a history associated with an electrical US and the non-reinforced trials of GS in extinction further suggested its safety, perhaps rendering its overall threat level (and hence opportunity for ambiguity) lower than the CS+ in extinction.

The finding that trait anxious individuals only showed resistance to fear extinction for the CS + but not for a GS is conceptually parallel to studies that found a novelty-facilitated extinction effect (Dunsmoor, Campese, Ceceli, LeDoux, & Phelps, 2015; Lucas, Luck, & Lipp, 2018). In these studies, one group of participants was exposed to standard fear extinction with the CS + after acquisition (EXT group). Another group of participants instead received CS-novel tone pairings (NFE group). One common finding from these studies was that individuals high in intolerance of uncertainty, a trait associated with negative interpretation of threat ambiguity (e.g., Dugas, Buhr, & Ladouceur, 2004a; Dugas, Schwartz, & Francis, 2004b), showed more return of fear; however this pattern was only observed in the EXT group. This finding supports the idea that an extinguished CS + has an ambiguous threat value, consistent with the current finding that trait anxious individuals show a deficit in extinction learning, but only to the CS+.

Contrary to our second prediction, even though we used a GS highly similar to the CS in extinction, we still found that extinction learning to a GS was less effective in reducing conditioned fear to the CS+, or to a novel GS, when compared to direct extinction with the CS+. This finding is consistent with previous studies that found weak generalization of GS extinction (e.g., Barry et al., 2016; Vervliet et al., 2004, 2005; Zbozinek & Craske, 2018).

Although the stimuli in use were highly similar, the magnitude of the generalization of GS extinction effect was relatively small. According to associative accounts, this pattern can be explained by the protection from extinction effect via conditioned inhibition. When the GS was first presented in the ABA and ABC conditions, the novel elements uniquely possessed by the GS had no associative strength. The substantial drop in responding from the final A+ acquisition trial and the first B- extinction trial reflects generalization decrement to B, confirming that participants treated B as somewhat novel. Across extinction, these novel elements gradually gained inhibitory strength and acted as conditioned inhibitors, protecting the excitatory elements shared between the CS+ and the GS from extinction (Rescorla, 1969; see also; Pittig, Treanor, LeBeau, & Craske, 2018). In the case of the

ABA condition, the CS+ in test triggered conditioned fear because of the protected excitatory, shared elements, in addition to the unextinguished excitatory elements uniquely possessed by the CS+. In the case of the ABC condition, the novel GS was able to trigger conditioned fear because of the protected excitatory elements shared among the CS+ and the two GSs, in addition to the elements uniquely shared between the CS+ and the novel GS.

Although associative accounts are able to account for weak generalization of GS extinction via conditioned inhibition, they do predict robust generalization of GS extinction when the CS+ and GS are highly similar. Therefore, it is difficult to reconcile the prediction made by the associative accounts and the current findings. Alternatively, a cognitive account can also accommodate this pattern under the idea of protection from extinction (e.g., Lovibond, Davis, & O'Flaherty, 2000). Participants may have attributed the absence of an electrical US entirely to the novel features of the GS, despite the overall similarity of the GS to CS+. For instance, when a participant received an aqua-colored circle as CS+ and then received non-reinforced greener circles (GS) in extinction, he/she may have attributed the absence of an electrical US to the 'greenness' of the circle. Therefore, when this feature was absent or attenuated in the test stimulus, an electrical US may be expected.

However, a recent study found that extinction learning to a GS could actually generalize to other GSs more effectively than standard CS extinction (Struyf, Hermans, & Vervliet, 2018). This effect appears to depend on two particular conditions that were met in the Struyf et al. (2018) design. First, the GS in extinction had a higher level of intensity than the CS+ (a facial GS that had a higher level of fear expression than the CS+). Second, the GS in extinction was located in the opposite direction to CS- along the stimulus dimension. Under these two conditions, threat appraisal to the GS was maximized due to intensity bias and potential rule formation (i.e., the further the stimulus is away from CS-, the more likely US would be delivered). Therefore, presenting this GS in extinction would have triggered a large mismatch between threat expectancy and actual outcome (i.e., expectancy violation; Craske, Hermans, & Vervliet, 2018), potentially explaining the greater generalization of GS extinction observed. Our current findings and previous studies (e.g., Vervliet et al., 2005, 2004; Vervoort et al., 2014; Zbozinek & Craske, 2018) suggest that if the GS does not meet the aforementioned conditions, a weak generalization of GS extinction effect will be observed.

Aligning with our third prediction, trait anxious individuals showed higher US expectancies across test in both experiments when compared to low anxious individuals. However, this elevation in fear in test was not due to trait anxious individuals showing a weaker generalization of GS extinction effect nor a greater return of fear than low anxious individuals. In fact, both high and low anxious individuals showed a similar increase in US expectancies from extinction to test in the ABA condition (37% in the HA group and 38% in the LA group). Similarly, high and low anxious individuals showed a comparable increase in US expectancies from extinction to test in the ABC condition (41% and 44% respectively). Instead, the main effect of trait anxiety observed in test appears to reflect the persistence of an expectancy bias throughout extinction among trait anxious individuals, and a resistance to extinction in the high anxious group in the AAA and AAC conditions.

Unexpectedly, participants presented with a GS in extinction (ABA & ABC conditions) showed a more rapid decline in fear responding to the stimulus in the test phase than those presented with a CS in extinction (AAA & AAC conditions). This is a novel finding since previous studies in generalization of GS extinction reported the data averaged over test trials instead of on a trial-by-trial basis (e.g., Vervliet et al., 2004; Vervliet & Geens, 2014). Two possible factors may account for this pattern. First, the non-reinforced GS in extinction may have acted as an extra piece of information that strengthened the belief that the test stimulus was safe, especially after the first non-reinforced test trial. In fact, this interpretation is in line with studies that have shown facilitated generalization when multiple training exemplars are available (Dunsmoor, Martin, & LaBar, 2012; Lee, Lovibond, & Hayes, 2019). Second, participants who received a GS in extinction showed a higher level of conditioned fear on the first test trial compared to those who received standard CS extinction, therefore leaving more room for responding to the test stimulus to drop.

Since we used a single-cue conditioning procedure, it allowed us to solely focus on the generalization of GS extinction effect. As previously discussed, including a CS- may have rendered the interpretation of the findings difficult, since a reduction in responding to CS + after GS extinction could be attributed to the extinguished excitatory elements shared between the CS+ and GS (generalization of GS extinction effect), or to the inhibitory strength of the shared elements between CS+ and CS-, or a combination of both. Furthermore, in the case of the ABC condition, a reduction in responding to the novel GS in test could be attributed to the shared inhibitory elements between the CS-, the GS used in extinction and the test stimulus. Therefore, using a single-cue conditioning procedure gives us greater certainty to interpret the current finding as a pure test of generalization of GS extinction.

The finding of only a weak generalization of GS extinction effect suggests that extinction with a GS is a potential new pathway for the 'return of fear', especially evident in the ABC condition. Since it is highly unlikely that a therapist will be able to expose the original threat cues in treatment, patients are presumably instead exposed to cues that are perceptually or conceptually similar to the original threat cue. Similarly, they are unlikely to re-encounter the original threat cues after treatment, but they may well encounter novel similar cues. The heightened fear responses to a novel cue in test is conceptually equivalent to clinically anxious patients showing fear to novel objects or situations that resemble the original threat cue after successful treatment. However, despite this initial increase in fear responses, participants showed a sharp decline in conditioned fear after learning that the cue is non-threatening. This finding suggests that when patients encounter novel threatening cues after treatment, they will quickly learn that these cues are non-threatening, assuming they do not engage in avoidance (see Lovibond, Mitchell, Minard, Brady, & Menzies, 2009). Accordingly, exposing multiple stimuli in extinction may facilitate safety learning to novel cues. In fact, empirical evidence indicates that arachnophobes show stronger short- and long-term fear reduction after being exposed to different spider stimuli (Shiban, Schelhorn, Pauli, & Mühlberger, 2015). More recent studies also showed that presenting multiple stimuli in extinction led to a significant reduction in conditioned fear to the CS+ and other novel cues in test (Waters, Kershaw, & Lipp, 2018; Zbozinek & Craske, 2018). Additionally, the parallel between novelty-facilitated extinction (Dunsmoor et al., 2015; Lucas et al., 2018) and the current finding where CS extinction had higher threat ambiguity than GS extinction suggests that pairing fear-related stimuli with neutral stimuli during therapy may decrease their threat ambiguity, therefore improving treatment outcome (i.e., less return of fear).

The present study does have some limitations. First, we found only a limited number of significant effects on the skin conductance measure. One reason for this may be the large inter-individual variability of skin conductance (Lykken & Venables, 1971). Second, the apparent generalization of GS extinction effect in the ABC condition can be interpreted either as a generalization decrement from A to C, or a combination of generalization of GS extinction and generalization decrement. Future studies could investigate this issue further by first assessing the generalization decrement from A to C, therefore making it easier to unravel these two effects. Furthermore, given that C was further away from B than A along the color dimension (i.e., C was bluer than B relative to A), both associative and cognitive accounts would predict a similar level of responding to C, making it difficult to differentiate interpretations between both accounts. For instance, heightened responses to C could be interpreted as fewer common elements shared between C and B gaining inhibitory strength since C shared less common elements with B than with A. Alternatively, participants may

have formed a rule that the bluer the circle, the more likely it predicts an electrical US after experiencing a green circle in extinction, leading to an increase in responding to C. Future studies can manipulate the location of C, for example, making it further away from A (trained stimulus) than B (extinction stimulus), to help differentiate associative and cognitive accounts. Third, the significant decrease in US expectancies after GS extinction (ABA and ABC conditions) could be alternatively attributed to the previously mentioned lapse of time effect rather than to a pure GS extinction effect, or a combination of both. However, any such effect would have been equal in the two experimental conditions. In addition, all phases in the current study were carried out continuously in a short period of time (less than 15 min), so forgetting should have been minimal. Nonetheless, future research could include controls to isolate the effect of time per se.

In conclusion, although both GS extinction and CS extinction were able to reduce conditioned fear to the CS or to a different GS, extinction with a GS was less effective compared to extinction with the original CS. In other words, extinction with a GS led to a significant return of fear when participants were tested with CS + or another novel GS. The current work replicated previous findings of a weak generalization of GS extinction effect (Barry et al., 2016a; Vervliet & Geens, 2014; Vervliet et al., 2004; Zbozinek & Craske, 2018), despite using stimuli that were highly similar. Interestingly, participants who received a GS in extinction showed a sharp decrease in responding to the test stimuli across test. This was primarily because participants had received a different exemplar in extinction; after the first non-reinforced test trial, they were more willing to extrapolate that the test stimuli were safe, hence resulting in a more rapid decline in responding compared to those who received a CS in extinction. This suggests that presenting multiple extinction cues in exposure-based treatments may enhance treatment outcomes. Trait anxious individuals showed higher US expectancies across extinction and test compared to low anxious individuals. Trait anxiety was also found to slow down extinction learning, consistent with empirical findings in the literature (Dibbets et al., 2015; Gazendam et al., 2013). However, this pattern was only observed in participants who received standard fear extinction with the CS+. These findings align with the general principle that trait anxiety is associated with excessive threat appraisal to threat ambiguity.

Author contributions section

Alex H. K. Wong: Conceptualization, Formal analysis, Investigation, Methodology, Writing-Original Draft, Visualization, Software. **Peter F. Lovibond**: Conceptualization, Funding acquisition, Writing – Review & Editing, Supervision.

Acknowledgements

Alex H. K. Wong was supported by an Australian Postgraduate Award. This study was supported in part by a Discovery Project from the Australian Research Council (DP160101907) awarded to Peter F. Lovibond and Brett K. Hayes. This study was part of the project 'Cognitive processes in human emotional learning' (HC14003), that has been approved by the human Research Ethics Committee at the University of New South Wales.

References

Alvarez, R. P., Johnson, L., & Grillon, C. (2007). Contextual-specificity of short-delay extinction in humans: Renewal of fear-potentiated startle in a virtual environment. *Learning & Memory, 14*(4), 247–253. https://doi.org/10.1101/lm.493707.

Antony, M. M., Bieling, P. J., Cox, B. J., Enns, M. W., & Swinson, R. P. (1998). Psychometric properties of the 42-item and 21-item versions of the Depression Anxiety Stress Scales in clinical groups and a community sample. *Psychological Assessment, 10*(2), 176–181. https://doi.org/10.1037/1040-3590.10.2.176.

Barry, T. J., Griffith, J. W., Vervliet, B., & Hermans, D. (2016a). The role of stimulus specificity and attention in the generalization of extinction. *Journal of Experimental Psychopathology, 7*(1), 143–152. https://doi.org/10.5127/jep.048615.

Barry, T. J., Vervliet, B., & Hermans, D. (2016b). Threat-related gaze fixation and its relationship with the speed and generalisability of extinction learning. *Australian Journal of Psychology, 68*(3), 200–208. https://doi.org/10.1111/ajpy.12124.

Beckers, T., Krypotos, A.-M., Boddez, Y., Effting, M., & Kindt, M. (2013). What's wrong with fear conditioning? *Biological Psychology, 92*(1), 90–96. https://doi.org/10.1016/j.biopsycho.2011.12.015.

Blechert, J., Michael, T., Vriends, N., Margraf, J., & Wilhelm, F. H. (2007). Fear conditioning in posttraumatic stress disorder: Evidence for delayed extinction of autonomic, experiential, and behavioural responses. *Behaviour Research and Therapy, 45*(9), 2019–2033. https://doi.org/10.1016/j.brat.2007.02.012.

Blough, D. S. (1975). Steady state and a quantitative model of operant generalization and discrimination. *Journal of Experimental Psychology: Animal Behavior Processes, 1*(1), 3–21. https://doi.org/10.1037/0097-7403.1.1.3.

Boddez, Y., Vervliet, B., Baeyens, F., Lauwers, S., Hermans, D., & Beckers, T. (2012). Expectancy bias in a selective conditioning procedure: Trait anxiety increases the threat value of a blocked stimulus. *Journal of Behavior Therapy and Experimental Psychiatry, 43*, 832–837. https://doi.org/10.1016/j.jbtep.2011.11.005.

Boelen, P. A., & Reijntjes, A. (2009). Intolerance of uncertainty and social anxiety. *Journal of Anxiety Disorders, 23*(1), 130–135. https://doi.org/10.1016/j.janxdis.2008.04.007.

Bouton, M. E. (1993). Context, time, and memory retrieval in the interference paradigms of Pavlovian learning. *Psychological Bulletin, 114*(1), 80–99. https://doi.org/10.1037/0033-2909.114.1.80.

Bouton, M. E. (2002). Context, ambiguity, and unlearning: Sources of relapse after behavioural extinction. *Biological Psychiatry, 52*(10), 976–986. https://doi.org/10.1016/S0006-3223(02)01546-9.

Bouton, M. E., & Bolles, R. C. (1979). Contextual control of the extinction of conditioned fear. *Learning and Motivation, 10*(4), 445–466. https://doi.org/10.1016/0023-9690(79)90057-2.

Bouton, M. E., & García-Gutiérrez, A. (2006). Intertrial interval as a contextual stimulus. In: *Behavioural Processes, 71*(2–3), 307–317. https://doi.org/10.1016/j.beproc.2005.12.003.

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*(3), 248–265. https://doi.org/10.1037/0097-7403.9.3.248.

Brainard, D. H. (1997). The Psychophysics Toolbox. *Spatial Vision, 10*, 433–436.

Brown, T. A. (2007). Temporal course and structural relationships among dimensions of temperament and DSM-IV anxiety and mood disorder constructs. *Journal of Abnormal Psychology, 116*, 313–328.

Brown, T. A., Chorpita, B. F., Korotitsch, W., & Barlow, D. H. (1997). Psychometric properties of the depression anxiety stress Scales (DASS) in clinical samples. *Behaviour Research and Therapy, 35*(1), 79–89. https://doi.org/10.1016/S0005-7967(96)00068-X.

Chambers, J. A., Power, K. G., & Durham, R. C. (2004). The relationship between trait vulnerability and anxiety and depressive diagnoses at long-term follow-up of Generalized Anxiety Disorder. *Journal of Anxiety Disorders, 18*(5), 587–607. https://doi.org/10.1016/j.janxdis.2003.09.001.

Chan, C. K. Y., & Lovibond, P. F. (1996). Expectancy bias in trait anxiety. *Journal of Abnormal Psychology, 105*(4), 637–647. https://doi.org/10.1037/0021-843X.105.4.637.

Chen, J. T. H., & Lovibond, P. F. (2016). Intolerance of uncertainty is associated with increased threat appraisal and negative affect under ambiguity but not uncertainty. *Behavior Therapy, 47*(1), 42–53. https://doi.org/10.1016/j.beth.2015.09.004.

Clark, L. A., Watson, D., & Mineka, S. (1994). Temperament, personality, and the mood and anxiety disorders. *Journal of Abnormal Psychology, 103*, 103–116.

Craske, M. G., Hermans, D., & Vervliet, B. (2018). State-of-the-art and future directions for extinction as a translational model for fear and anxiety. *Philosophical Transactions of the Royal Society B: Biological Sciences, 373*(1742), 20170025. https://doi.org/10.1098/rstb.2017.0025.

Davis, M., Falls, W. A., & Gewirtz, J. (2000). Neural systems involved in fear inhibition: Extinction and conditioned inhibition. In M. S. Myslobodsky, & I. Weiner (Eds.). *Contemporary issues in modeling psychopathology* (pp. 113–141). Boston, MA: Springer US.

Dibbets, P., van den Broek, A., & Evers, E. A. T. (2015). Fear conditioning and extinction in anxiety- and depression-prone persons. *Memory, 23*(3), 350–364. https://doi.org/10.1080/09658211.2014.886704.

Dugas, M. J., Buhr, K., & Ladouceur, R. (2004a). The role of intolerance of uncertainty in etiology and maintenance. In R. G. Heimberg, C. L. Turk, & D. S. Mennin (Eds.). *Generalized anxiety disorder: Advances in research and practice* (pp. 143–163). New York: Guilford Press.

Dugas, M. J., Gagnon, F., Ladouceur, R., & Freeston, M. H. (1998). Generalized anxiety disorder: A preliminary test of a conceptual model. *Behaviour Research and Therapy, 36*(2), 215–226. https://doi.org/10.1016/S0005-7967(97)00070-3.

Dugas, M. J., Schwartz, A., & Francis, K. (2004b). Brief report: Intolerance of uncertainty, worry, and depression. *Cognitive Therapy and Research, 28*(6), 835–842. https://doi.org/10.1007/s10608-004-0669-0.

Dunsmoor, J. E., Campese, V. D., Ceceli, A. O., LeDoux, J. E., & Phelps, E. A. (2015). Novelty-facilitated extinction: Providing a novel outcome in place of an expected threat diminishes recovery of defensive responses. *Biological Psychiatry, 78*, 203–209. https://doi.org/10.1016/j.biopsych.2014.12.008.

Dunsmoor, J. E., Martin, A., & LaBar, K. S. (2012). Role of conceptual knowledge in learning and retention of conditionedfear. *Biological Psychology, 89*, 300–305. https://doi.org/10.1016/j.biopsycho.2011.11.002.

Fetzner, M. G., Horswill, S. C., Boelen, P. A., & Carleton, R. N. (2013). Intolerance of uncertainty and PTSD symptoms: Exploring the construct relationship in a community sample with a heterogeneous trauma history. *Cognitive Therapy and Research,*

37(4), 725–734. https://doi.org/10.1007/s10608-013-9531-6.
Gazendam, F. J., Kamphuis, J. H., & Kindt, M. (2013). Deficient safety learning characterizes high trait anxious individuals. *Biological Psychology, 92*(2), 342–352. https://doi.org/10.1016/j.biopsycho.2012.11.006.
Genheimer, H., Andreatta, M., Asan, E., & Pauli, P. (2017). Reinstatement of contextual conditioned anxiety in virtual reality and the effects of transcutaneous vagus nerve stimulation in humans. *Scientific Reports, 7*, 17886. https://doi.org/10.1038/s41598-017-18183-3.
Gershuny, B. S., & Sher, K. J. (1998). The relation between personality and anxiety: Findings from a 3-year prospective study. *Journal of Abnormal Psychology, 107*(2), 252–262. https://doi.org/10.1037/0021-843X.107.2.252.
Henry, J. D., & Crawford, J. R. (2005). The short-form version of the depression anxiety stress Scales (DASS-21): Construct validity and normative data in a large non-clinical sample. *British Journal of Clinical Psychology, 44*(Pt 2), 227. https://doi.org/10.1348/014466505X29657.
Hermann, C., Ziegler, S., Birbaumer, N., & Flor, H. (2002). Psychophysiological and subjective indicators of aversive pavlovian conditioning in generalized social phobia. *Biological Psychiatry, 52*(4), 328–337. https://doi.org/10.1016/S0006-3223(02)01385-9.
Hermans, D., Dirikx, T., Vansteenwegenin, D., Baeyens, F., Van den Bergh, O., & Eelen, E. (2005). Reinstatement of fear responses in human aversive conditioning. *Behaviour Research and Therapy, 43*(4), 533–551. https://doi.org/10.1016/j.brat.2004.03.013.
Huff, N. C., Hernandez, J. A., Blanding, N. Q., & LaBar, K. S. (2009). Delayed extinction attenuates conditioned fear renewal and spontaneous recovery in humans. *Behavioral Neuroscience, 123*(4), https://doi.org/10.1037/a0016511 843-843.
Jorm, A. F., Christensen, H., Henderson, A. S., Jacomb, P. A., Korten, A. E., & Rodgers, B. (2000). Predicting anxiety and depression from personality: Is there a synergistic effect of neuroticism and extraversion?. *Journal of Abnormal Psychology, 109*(1), 145–149. https://doi.org/10.1037/0021-843X.109.1.145.
La Greca, A. M., Silverman, W. K., & Wasserstein, S. B. (1998). Children's predisaster functioning as a predictor of posttraumatic stress following Hurricane Andrew. *Journal of Consulting and Clinical Psychology, 66*(6), 883–892. https://doi.org/10.1037/0022-006x.66.6.883.
Lee, J. C., Hayes, B. K., & Lovibond, P. F. (2018). Peak shift and rules in human generalization. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 44*(12), 1955–1970. https://doi.org/10.1037/xlm0000558.
Lee, J. C., Lovibond, P. F., & Hayes, B. K. (2019). Evidential diversity increases generalization in predictive learning. *Quarterly Journal of Experimental Psychology, 72*(11), 2647–2657. https://doi.org/10.1177/1747021819857065.
Lissek, S., Pine, D. S., & Grillon, C. (2006). The strong situation: A potential impediment to studying the psychobiology and pharmacology of anxiety disorders. *Biological Psychology, 72*(3), 265–270. https://doi.org/10.1016/j.biopsycho.2005.11.004.
Lovibond, P. (1998). Long-term stability of depression, anxiety, and stress syndromes. *Journal of Abnormal Psychology, 107*(3), 520–526. https://doi.org/10.1037//0021-843X.107.3.520.
Lovibond, P. F., Davis, N., & O'Flaherty, A. (2000). Protection from extinction in human fear conditioning. *Behaviour Research and Therapy, 38*, 967–983. https://doi.org/10.1016/S0005-7967(99)00121-7.
Lovibond, S. H., & Lovibond, P. F. (1995a). *Manual for the depression anxiety stress Scales* (2nd ed.). Sydney Psychology Foundation.
Lovibond, P. F., & Lovibond, S. H. (1995b). The structure of negative emotional states: Comparison of the depression anxiety stress Scales (DASS) with the beck depression and anxiety inventories. *Behaviour Research and Therapy, 33*(3), 335–343. https://doi.org/10.1016/0005-7967(94)00075-U.
Lovibond, P. F., Mitchell, C. J., Minard, E., Brady, A. J., & Menzies, R. (2009). Safety behaviours preserve threat beliefs: Protection from extinction of human fear conditioning by an avoidance response. *Behaviour Research and Therapy, 47*, 716–720. https://doi.org/10.1016/j.brat.2009.04.013.
Lucas, K., Luck, C. C., & Lipp, O. V. (2018). Novelty-facilitated extinction and the reinstatement of conditional human fear. *Behaviour Research and Therapy, 109*, 68–74. https://doi.org/10.1016/j.brat.2018.08.002.
Lykken, D. T., & Venables, P. H. (1971). Direct measurement of skin conductance: A proposal for standardization. *Psychophyiology, 8*(5), 656–672. https://doi.org/10.1111/j.1469-8986.1971.tb00501.x.
Mackintosh, N. J. (1974). *The psychology of animal learning.* London: Academic Press.
McLaren, I. P., & Mackintosh, N. J. (2002). Associative learning and elemental representation: II. Generalization and discrimination. *Animal Learning & Behavior, 30*(3), 177–200. https://doi.org/10.3758/BF03192828.
Michael, T., Blechert, J., Vriends, N., Margraf, J., & Wilhelm, F. H. (2007). Fear conditioning in panic disorder: Enhanced resistance to extinction. *Journal of Abnormal Psychology, 116*(3), 612–617. https://doi.org/10.1037/0021-843X.116.3.612.
Morriss, J., Christakou, A., & van Reekum, C. M. (2016). Nothing is safe: Intolerance of uncertainty is associated with compromised fear extinction learning. *Biological Psychology, 121*, 187–193. https://doi.org/10.1016/j.biopsycho.2016.05.001.
Orr, S. P., Metzger, L. J., Lasko, N. B., Macklin, M. L., Peri, T., & Pitman, R. K. (2000). De novo conditioning in trauma-exposed individuals with and without posttraumatic stress disorder. *Journal of Abnormal Psychology, 109*(2), 290–298. https://doi.org/10.1037/0021-843X.109.2.290.
Pavlov, I. P. (1927). *Conditioned reflexes: An investigation of the physiological activity of the cerebral cortex.* Oxford: Oxford University Press.
Peri, T., Ben-Shakhar, G., Orr, S. P., & Shalev, A. Y. (2000). Psychophysiologic assessment of aversive conditioning in posttraumatic stress disorder. *Biological Psychiatry, 47*(6), 512–519. https://doi.org/10.1016/S0006-3223(99)00144-4.
Pittig, A., Treanor, M., LeBeau, R. T., & Craske, M. G. (2018). The role of associative fear and avoidance learning in anxiety disorders: Gaps and directions for future research. *Neuroscience & Biobehavioral Reviews, 88*, 117–140. https://doi.org/10.1016/j.neubiorev.2018.03.015.
Rescorla, R. A. (1969). Pavlovian conditioned inhibition. *Psychological Bulletin, 72*(2), 77–94. https://doi.org/10.1037/h0027760.
Scheveneels, S., Boddez, Y., Vervliet, B., & Hermans, D. (2016). The validity of laboratory-based treatment research: Bridging the gap between fear extinction and exposure treatment. *Behaviour Research and Therapy, 86*, 87–94. https://doi.org/10.1016/j.brat.2016.08.015.
Shiban, Y., Schelhorn, I., Pauli, P., & Mühlberger, A. (2015). Effect of combined multiple contexts and multiple stimuli exposure in spider phobia: A randomized clinical trial in virtual reality. *Behaviour Research and Therapy, 71*, 45–53. https://doi.org/10.1016/j.brat.2015.05.014.
Struyf, D., Hermans, D., & Vervliet, B. (2018). Maximizing the generalization of fear extinction: Exposures to a peak generalization stimulus. *Behaviour Research and Therapy, 111*, 1–8. https://doi.org/10.1016/j.brat.2018.09.005.
The MathWorks Inc (2014). *Matlab – the language of technical computing.* Massachusetts: Natick Version R2014b (9.5).
Vansteenwegen, D., Vervliet, B., Iberico, C., Baeyens, F., Van den Bergh, O., & Hermans, D. (2007). The repeated confrontation with videotapes of spiders in multiple contexts attenuates renewal of fear in spider-anxious students. *Behaviour Research and Therapy, 45*, 1169–1179. https://doi.org/10.1016/j.brat.2006.08.023.
Vervliet, B., & Geens, M. (2014). Fear generalization in humans: Impact of feature learning on conditioning and extinction. *Neurobiology of Learning and Memory, 113*, 143–148. https://doi.org/10.1016/j.nlm.2013.10.002.
Vervliet, B., Vansteenwegen, D., Baeyens, F., Hermans, D., & Eelen, P. (2005). Return of fear in a human differential conditioning paradigm caused by a stimulus change after extinction. *Behaviour Research and Therapy, 43*(3), 357–371. https://doi.org/10.1016/j.brat.2004.02.005.
Vervliet, B., Vansteenwegen, D., & Eelen, P. (2004). Generalization of extinguished skin conductance responding in human fear conditioning. *Learning & Memory, 11*, 555–558. http://www.learnmem.org/cgi/doi/10.1101/lm.77404.
Vervliet, B., Vansteenwegen, D., & Eelen, P. (2006). Generalization gradients for acquisition and extinction in human contingency learning. *Experimental Psychology, 53*(2), 132–142. https://doi.org/10.1027/1618-3169.53.2.132.
Vervoort, E., Vervliet, B., Bennett, M., & Baeyens, F. (2014). Generalization of human fear acquisition and extinction within a novel arbitrary stimulus category. *PLoS One, 9*(5), e96569. https://doi.org/10.1371/journal.pone.0096569.
Waters, A. M., Kershaw, R., & Lipp, O. V. (2018). Multiple fear-related stimuli enhance physiological arousal during extinction and reduce physiological arousal to novel stimuli and the threat conditioned stimulus. *Behaviour Research and Therapy, 106*, 28–36. https://doi.org/10.1016/j.brat.2018.04.005.
Weems, C. F., Pina, A. A., Costa, N. M., Watts, S. E., Taylor, L. K., & Cannon, M. F. (2007). Predisaster trait anxiety and negative affect predict posttraumatic stress in youths after Hurricane Katrina. *Journal of Consulting and Clinical Psychology, 75*(1), 154–159. https://doi.org/10.1037/0022-006x.75.1.154.
Wong, A. H. K., & Lovibond, P. F. (under review). Breakfast or bakery? The role of categorical ambiguity in over-generalization of learned fear in trait anxiety.
Wong, A. H. K., & Lovibond, P. F. (2017). Rule-based generalization in single-cue and differential fear conditioning in humans. *Biological Psychology, 129*, 111–120. https://doi.org/10.1016/j.biopsycho.2017.08.056.
Wong, A. H. K., & Lovibond, P. F. (2018). Excessive generalization of conditioned fear in trait anxious individuals under ambiguity. *Behaviour Research and Therapy, 107*, 53–63. https://doi.org/10.1016/j.brat.2018.05.012.
Zbozinek, T. D., & Craske, M. G. (2018). Pavlovian extinction of fear with the original conditional stimulus, a generalization stimulus, or multiple generalization stimuli. *Behaviour Research and Therapy, 107*, 64–75. https://doi.org/10.1016/j.brat.2018.05.009.