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Costly avoidance triggered by categorical fear generalization

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ABSTRACT

Fear generalization refers to the spread of acquired fear to novel stimuli that resemble the original fear-related stimulus. Preliminary evidence suggests that excessive fear generalization is a pathogenic feature of anxiety disorders, however, it remains unclear how fear generalization affects pathological avoidance. The current study thus aimed to examine the link between categorical fear generalization and costly avoidance. By combining a fear acquisition training phase and an avoidance test, the current findings showed that acquired fear spreads to novel stimuli that belonged to the same category of the original fear-related stimuli, but not to those that belonged to the fear-irrelevant categories. Importantly, participants avoided these fear-related novel stimuli despite costs. The current findings indicate that categorical fear generalization triggers costly avoidance. In terms of clinical implication, a decrease in costly avoidance aligned with a decrease in US expectancies. This emphasizes that behavioral approach may initiate extinction learning.

Avoidance of fear-related stimuli (i.e., fear avoidance) is a core feature for the development and maintenance of anxiety disorders (Craske, 1999; Dymond & Roche, 2009). Pathological avoidance is considered maladaptive since patients with anxiety disorders often avoid fear-related stimuli or situations, preventing them from learning that these stimuli or situations pose no actual threat (Barlow, 2002). Furthermore, pathological avoidance is oftentimes costly, meaning that avoidance is linked to impairments and the loss of competing positive outcomes (Pittig, Schulz, Craske, & Alpers, 2014). For instance, an individual with social anxiety may avoid any social interactions at the cost of positive interpersonal relationship or impaired day-to-day functioning (Mendlowicz & Stein, 2000; Olatunji, Cisler, & Tolin, 2007). Therefore, controlled laboratory investigation of the mechanism underlying costly avoidance of fear-related stimuli is important for the understanding of anxiety disorders (see also Pittig, Wong, Glück, & Boschet, 2020).

Laboratory studies examining fear avoidance commonly combined Pavlovian fear learning with instrumental responses (e.g., Dymond, Schlund, Roche, De Houwer, & Freegard, 2012; Lovibond, Mitchell, Minard, Brady, & Menzies, 2009; Lovibond, Saunders, Weidemann, & Mitchell, 2008; Vervliet & Indekeu, 2015). Specifically, participants are presented with a fear-related stimulus (CS+) that is followed by an aversive unconditioned stimulus (US) during Pavlovian fear acquisition. Next, they learn that performing a designated response during CS+ presentation can effectively prevent the upcoming US (i.e., avoidance response). A common finding among these studies is that avoidance responses are quickly acquired and conditioned fear to the CS+ reduces once an individual makes an avoidance response (Lovibond et al., 2009, 2008; Pittig, 2019). These studies provide important insight into the interplay between fear and avoidance learning, for instance, that acquired fear to the original CS+ reliably triggers subsequent avoidance responses to this specific stimulus (Lovibond et al., 2009).

Most of the aforementioned studies, however, investigated low-cost avoidance. Low-cost avoidance typically incorporates a simple response with minimal costs (e.g., effort for button pressing). It arguably does not tap into the pathological domain of fear avoidance, given that the substantial cost of avoidance is thought to give pathological fear avoidance its maladaptive quality (American Psychiatric Association, 2013). In support, high and low anxious individuals showed comparable levels of low-cost avoidance, but costly avoidance was elevated in anxious individuals (Pittig & Scherbaum, 2020). To examine pathological avoidance more closely in a laboratory setting, more recent studies have focused on examining costly fear avoidance (e.g., Meulders, Franssen, Fonteyne, & Vlaeyen, 2016; Pittig et al., 2014; Van Meurs, Wigggert, Wicker, & Lissek, 2013).

One particular paradigm examines how acquired fear motivates avoidance despite being in conflict with obtaining positive outcomes (i.e., approach-avoidance conflict; Pittig et al., 2014). In this study, two groups of participants underwent differential fear acquisition training,

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in which a CS+ was followed by an aversive US and another stimulus that was never followed by an US (CS-). In a following decision task, participants had to choose one of two options. One option was linked to a higher probability of hypothetical reward (high-reward option) while the other deck was linked to a lower probability of hypothetical reward (low-reward option). However, selecting the high-reward option led to a presentation of the CS+. In contrast, selecting the low-reward option led to a presentation of CS-. The results showed that participants were less likely to choose the high-reward option compared to another group of participants who received novel stimuli after choosing either options that had not been presented in fear acquisition training. Choosing the low-reward option in the former group can be seen as an index of costly fear avoidance – participants actively avoided presentation of the fear-related stimulus (i.e., the presentation of CS+), by choosing the low-reward option. Furthermore, since CS+ was no longer reinforced in test, avoiding the option linked to it became unnecessary. Interestingly, stronger avoidance was linked to elevated SCRs to the CS+. Specifically, the magnitude of SCRs to CS+ in initial decision was positively linked to behavioral avoidance throughout the task, suggesting that avoidance was indeed motivated by acquired fear to CS+. This study was also one of the earliest studies to examine CS-avoidance within a fear conditioning framework, in which individuals avoided the presentation of CS+ and hence the upcoming US. This arguably resembles how individuals with clinical anxiety avoid fear-related objects or situations in order to prevent a perceived threatening outcome (see Pittig et al., 2020). Following studies also found such costly avoidance, indicated by a lower tendency to choose an optimal option linked to either a CS+ (Bublatzky, Alpers, & Pittig, 2017; Pittig & Dehler, 2019) or an US (Rattel, Miedl, Blechert, & Wilhelm, 2017). Collectively, these studies demonstrate how costly avoidance is triggered once the optimal option is associated with fear.

These studies, however, are restricted to costly fear avoidance to the original fear stimulus, i.e., to the stimulus that was directly associated with an aversive outcome. It is known that acquired fear is not confined to the original CS+. Novel stimuli that resemble CS+ are also able to trigger fear responses, despite never being directly paired with an aversive US before. This spread of acquired fear is known as fear generalization. For example, perceptual fear generalization, where acquired fear spreads to novel stimuli that perceptually resemble the original CS+, was empirically demonstrated in numerous studies in humans (e.g., Lee, Hayes, & Lovibond, 2018; Livesey & McLaren, 2009; Thomas, Lusky, & Morrison, 1992; Wong & Lovibond, 2017). Preliminary evidence suggests that over-generalization of fear is another core feature of anxiety disorders (see Pittig Treanor, LeBau & Craske, 2018). Individuals with anxiety disorders compared to healthy controls showed stronger fear responding to novel generalization stimuli (GSs) that slightly resemble the CS+ perceptually (Kaczkurkin et al., 2017; Lissek et al., 2014, 2010). Moreover, stimuli that lack any physical resemblance to CS+ can also trigger generalized fear. For instance, fear memories of a traumatic event in post-traumatic stress disorder can be triggered by various reminder stimuli that do not necessarily resemble the traumatic event in a physical way, but are conceptually connected (Parsons & Ressler, 2013). This suggests that stimuli conceptually related to the fear-related stimulus are able to trigger fear. In fact, conceptual fear generalization is arguably more clinically relevant given that stimuli with multiple perceptual dimensions are usually involved in real-world situations (Dunsmoor & Murphy, 2015; Dymond, Dunsmoor, Vervliet, Roche, & Hermans, 2015).

In light of this, recent studies have focused on how fear generalizes conceptually, for instance, via a semantic pathway (e.g., Boyle, Roche, Dymond, & Hermans, 2016) or a symbolic pathway (Dymond et al., 2011; 2014). Other studies focused on how fear generalizes across categories. For instance, Dunsmoor and Murphy (2014) presented exemplars from one category (e.g., bird) reinforced with an aversive US (CS+ category) and exemplars from another category (e.g., mammal) that were never reinforced (CS- category). In the following test phase, participants showed heightened SCRs and US expectancies to novel exemplars that belonged to the CS+ category (categorical fear stimuli). Fear responses to these categorical fear stimuli strongly suggest that fear generalizes at a categorical level since test stimuli were perceptually different to the CS+ exemplars. Categorical fear generalization has been replicated in other laboratory studies (e.g., Bennett, Vervoort, Boddez, Hermans, & Baeyens, 2015; Meulders, Vandael, & Vlaeyen, 2017; Vervoort, Vervliet, Bennett, & Baeyens, 2014; Wong & Lovibond, accepted). Given the explanatory power of conceptual generalization on the wide spread of fear and its relevance for anxiety disorders, it is important to understand how conceptual fear generalization impacts avoidance behavior.

The current study sought to examine whether novel categorical fear stimuli (i.e., stimuli that have never been directly paired with an aversive outcome but are categorically related to CS+) trigger costly avoidance. Combining categorical fear generalization with a paradigm assessing costly avoidance (see Pittig et al., 2014), participants were first trained with several CS+ exemplars that belonged to the same category (e.g., animal) and several CS- exemplars from another category (e.g., fruit). In the following avoidance test, participants in the Generalization group had to choose between two decks, a high-reward option and a low-reward option. The high-reward option led to a higher probability of reward, but was always followed by a novel categorical fear stimulus. On the other hand, the low-reward option led to a lower probability of reward, but was always followed by a novel stimulus that belonged to the CS- category (categorical safety stimulus). In a Control group, reward contingencies were the same, however, choosing either option led to novel stimuli that belonged to neither the CS+ nor the CS- category (i.e., novel stimuli that were fear-irrelevant; fear-irrelevant categories). We hypothesized that participants in the Generalization group would less frequently choose the high-reward option compared to the Control group, suggesting costly avoidance of GSs categorically related to fear stimuli (GS-avoidance).

1. Method

1.1. Participants

Undergraduate students were recruited as participants who received either course credit or 10€ for participation. Participants were randomly assigned into the Generalization group or the Control group. A total of 64 participants were recruited, with 32 participants in each group.[1] The experimental procedure was approved by the Ethics Committee of the Institute of Psychology at the University of Würzburg (GZ 2018–17).

1.2. Apparatus and materials

A computer equipped with Presentation software (Neurobehavioral Systems, Inc., Berkeley, CA, Version 20.1) generated all visual stimuli presented to the participants and recorded the expectancy ratings, while another computer controlled BrainVision recorder (Brain Products GmbH, Gilching, Germany) to record the skin conductance data via two Ag/AgCl electrodes at a sampling rate of 1000Hz throughout the experiment.

Six pictures of animal exemplars (bear, cat, cow, dog, gorilla and rabbit), 6 fruit exemplars (apple, banana, grape, pear, pineapple and lemon), 3 tool exemplars (hammer, wrench, screwdriver) and 3 vehicle exemplars (bus, car, truck) were used. All of these images were standardized 2D black and white drawings from Snodgrass and Vanderwart

[1] Sample size was based on power analyses carried out with G-power (Faul, Erdfelder, Lang, & Buchner, 2007). In order to detect medium effect sizes (Cohen's $f = 0.3$; based on Pittig et al., 2014) with 80% power, a minimum of 54 participants were required.

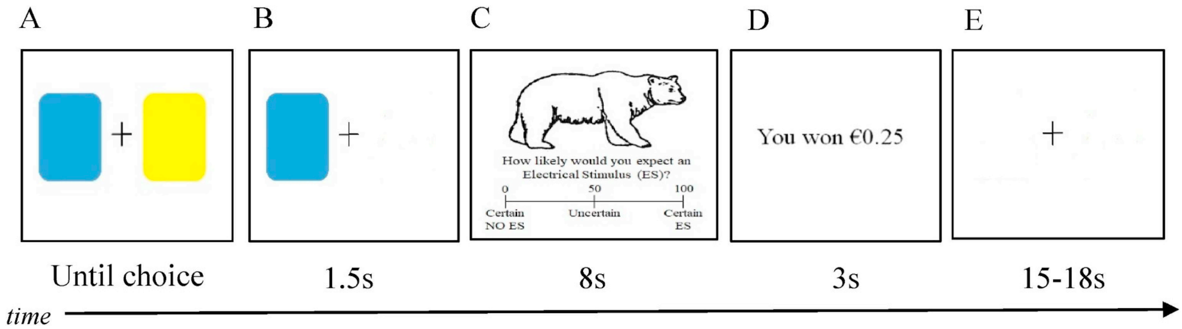

Fig. 1. Example of the trial structure in the avoidance test. (A) Participants had to select one of the two decks presented. (B) The selected deck remained on the screen for 1.5s. (C) Depending on choice, a novel exemplar that belonged to the CS+ or the CS- category was presented for 8s in the Generalization group, while a novel exemplar that belonged to neither the CS categories was presented for 8s in the Control group. Participants were asked to indicate their US expectancies. (D) Reward feedback was presented for 3s. (E) The ITI was randomized between 15 and 18s.

(1980). Half of the animal and fruit exemplars served as CSs during fear acquisition training for both groups. In the subsequent avoidance test, the remaining half of the animal and fruit exemplars were presented in the Generalization group, while the tool and vehicle exemplars were presented in the Control group.

1.3. Procedure

After providing written informed consent, participants were asked to fill in the German version of DASS-21 (Lovibond & Lovibond, 1995; Nilges & Essau, 2015). The DASS-21 is a short version of the original DASS (Depression Anxiety Stress Scale), which measures and discriminates between three constructs: depression, anxiety and stress. Both the DASS and DASS-21 have been shown to validly measure these three constructs (Antony, Bieling, Cox, Enns, & Swinson, 1998; Brown, Chorpita, Korotitsch, & Barlow, 1997; Henry & Crawford, 2005; Lovibond, 1998). The electrical stimulation electrodes and skin conductance electrodes were then attached. Skin conductance electrodes were attached to the hypothenar muscles on the palm of the non-dominant hand. Participants were then led through a calibration procedure in which they selected a level of US intensity that was 'definitely uncomfortable but not painful'. The aversive US was an electrical stimulation consisting of 125 pulses separated by 5 ms generated from a DS7A Digitimer stimulator. The US was delivered through a bar electrode attached to the wrist of the same hand. The study consisted of a fear acquisition training phase followed by an avoidance test.

Fear acquisition training. Participants were informed that different pictures would be presented on the computer screen, which may or may not be followed by an electrical stimulation. They were asked to learn the relationship between the pictures and electrical stimulation. Participants were informed to indicate their expectancy of electrical stimulation using a visual analog scale (VAS) during the presentation of the picture (see Supplementary Materials for the exact instructions). The VAS ranged from 0 to 100, in which 0 indicates certain no electrical stimulation and 100 indicates certain electrical stimulation. Fear acquisition training was divided into two blocks. In each block, three different animal exemplars and three different fruit exemplars served as the CSs, and were presented twice each, resulting in 12 trials per block. The CS+ exemplars were reinforced at a 75% rate while the CS- exemplars were never reinforced. The CS+ exemplars were partially reinforced to slow down extinction learning in the subsequent avoidance test (see Chan & Harris, 2019; Humphreys, 1939) since all stimuli were not reinforced in test. The categories that served as CS+ and CS- were counterbalanced across participants. The presentation order was pseudo-randomized so that the first CS+ exemplar and the last CS+ exemplar were always followed by an US, and the same trial type never appeared more than twice in a row. The CSs were presented along with the US expectancy VAS for 8s. If scheduled, the US was presented immediately after CS+ offset. The inter-trial interval (ITI) varied between 15 and 18s.

Avoidance test. Participants were informed that they could freely choose between a blue and yellow deck on each trial, which may or may not be followed by a hypothetical reward. They were also told that the aim of this task was to gain as much hypothetical financial reward as possible. For both groups, choosing either deck led to the same amount of hypothetical reward (0.25€), but one deck (e.g., blue) was associated with a higher probability of gaining the reward (60%) while the other deck (e.g., yellow) was associated with a lower reward probability (40%). Therefore, the former deck represents the high-reward option while the latter deck represents the low-reward option. A previous study has shown that participants were able to distinguish between the high and low rewards with these reward contingencies (Pittig et al., 2014). Furthermore, using the same reward probabilities allows better comparison between the current study and previous work. Importantly, participants were not informed about the reward contingencies, therefore they had to learn through direct experience. The color of the decks that served as the high- and low-reward option were counterbalanced across participants. Participants were also informed that some pictures would be presented after the decks offset, which could potentially be followed by an US. Such instructions were delivered for two reasons. First, to minimize any non-associative learning changes to the generalized fear due to the shift in context between phases by maintaining participants' anticipatory fear. Secondly, the instructions prepared participants to make their US expectancy ratings for each stimulus in the avoidance test. Unbeknown to the participants, no US was actually delivered in test.

For the Generalization group, choosing the high-reward option always led to a presentation of a novel exemplar from the CS+ category (GS+) for 8s, followed by a presentation of reward feedback (i.e., whether a reward was won or not) for 3s (see Fig. 1). In contrast, choosing the low-reward option always led to a presentation of a novel exemplar from the CS- category (GS-) for 8s, which was also followed by a 3-s reward feedback. For the Control group, both high- and low-reward options led to novel exemplars that neither belonged to the CS+ nor the CS- category (i.e., tool and vehicle) for 8s, followed by a 3-s reward feedback. As previously mentioned, the presentation of fear-irrelevant novel exemplars (NS) in the Control group controlled for an unspecific effect of fear acquisition on subsequent costly avoidance (see also Pittig et al., 2014). Specifically, a novel exemplar from a fear-irrelevant category (e.g., tool) was presented after the high-reward option (NS–H) while a novel exemplar from another fear-irrelevant category (e.g., vehicle) was presented after the low-reward option (NS-L). The US expectancy VAS appeared with every GS or NS presentation, where participants were prompted to indicate their US expectancies.

The avoidance test was divided into three blocks of 10 trials each. For both groups, novel GSs or NSs were presented in each block. For instance, the GSs shown in the first test block of the Generalization group were a dog (GS+) or a lemon (GS-), while the GSs shown in the second test block were a gorilla (GS+) or a pear (GS-).

1.4. Scoring and analysis

We applied a 1-Hz high-pass filter to remove high frequency noise and a notch filter (50Hz) to the skin conductance data. Next, SCRs were calculated by finding the difference between the maximum response and the corresponding trough in the interval of 1s after CS onset to CS offset (see Pineles, Orr, & Orr, 2009). SCRs were square root transformed to obtain normal distribution (Boucsein et al., 2012).

Planned contrasts were used to compare groups and to assess acquisition and generalization to novel stimuli in test. For acquisition, three orthogonal repeated measures contrasts were used. First, the averaged responding to CS+ was compared to those to CS- in both expectancy ratings and skin conductance. Second, responding to the CSs in the second block was compared to the first block to examine whether there were any differences in responding between blocks. Third, the interaction of these two contrasts (CS type and Block) examined the development of differential responding to the CSs. These analyses served as a manipulation check for successful acquisition of conditioned fear in both groups. For the avoidance test, we assessed expectancy ratings and skin conductance responses to the stimuli following the *first* high- and low-reward options for each block. That means, responding to the stimulus type following the reward options were compared (i.e., GS+ vs GS-, NS-H vs NS-L). A linear trend repeated measures contrast across blocks assessed whether responding to stimuli changes across test (i.e., extinction). We also examined the resulting interaction of these two contrasts (Stimulus type and Linear trend) to evaluate whether any changes in responding across test blocks differed between stimulus types. These analyses served as the cognitive and physiological indices for fear generalization. All interactions between the group and repeated measures contrasts were then tested to evaluate group differences in both acquisition and test. Critically, for the behavioral avoidance data, a between-group contrast was used to capture any group differences in choosing a low-reward option across the three test blocks (i.e., group differences in costly avoidance). A linear trend repeated measures contrast was used to assess whether there was a change in preference of choosing a low-reward option across test. The interaction between the group and linear trend contrasts was examined to evaluate if there were any group differences in the change in preference of choosing a low-reward option across test.

Analyzing generalization of fear and how it may impact subsequent behavioral decisions requires participants to have acquired fear to the CS+ exemplars in the first place. Therefore, statistical analyses were restricted to participants who satisfied an acquisition criterion, that is, participants who demonstrated differential conditioning in their expectancy ratings. Differential conditioning between CS+ and CS- was defined by an average difference of at least 50 in the last acquisition block (i.e., the last 6 trials of CS+ and the last 6 trials of CS-). A total of 7 participants (4 in the Generalization group and 3 in the Control group) were excluded based on this criterion. This left 28 participants in the Generalization group and 29 participants in the Control group.[2] Table 1 shows the demographic and DASS-21 data. Although there was a noticeable difference in trait anxiety scores between groups, this difference did not reach significance $F(1,55) = 3.8$, $p = 0.06$, $\eta_p^2 = 0.06$. In addition, according to the Manual for DASS (Lovibond & Lovibond, 1995), an anxiety score below 8 is classified as lying within a normal range of anxiety level. In other words, both groups consisted of low anxious individuals. No other group differences emerged (highest $F = 2.4$, $p = 0.1$).

[2] Analyses including these participants were similar to the main analyses below. Importantly, all critical tests remained significant albeit with smaller effect sizes.

2. Results

2.1. Fear acquisition training

Fig. 2A shows the mean US expectancy ratings across acquisition for both groups. A significant main effect of CS type was observed, $F(1,55) = 1283.2$, $p < 0.01$, $\eta_p^2 = 0.99$, in contrast, we did not find a significant main effect of Block, $F(1,55) = 0.09$, $p = 0.8$, $\eta_p^2 < 0.01$. US expectancy ratings to CS+ increased across blocks, while an opposite pattern was observed in ratings to CS-, indicated by a significant interaction between CS type and Block, $F(1,55) = 132.0$, $p < 0.01$, $\eta_p^2 = 0.71$; follow-up analyses confirmed this pattern for both CS+ across blocks, $F(1,55) = 49.7.0$, $p < 0.01$, $\eta_p^2 = 0.47$ and CS- across blocks, $F(1,55) = 87.4$, $p < 0.01$, $\eta_p^2 = 0.61$. Importantly, no interactions involving Group were observed (highest $F = 2.1$, $p = 0.15$). In sum, both groups successfully acquired higher US expectancy ratings to the CS+ compared to the CS-, without significant differences between groups.

Fig. 2B shows the square rooted SCR during acquisition in both groups. Averaged across groups and blocks, participants showed elevated responding to the CS+ compared to the CS-, supported by a main effect of CS type, $F(1,55) = 32.7$, $p < 0.01$, $\eta_p^2 = 0.37$. Responding to both CS types decreased across blocks, confirmed by a significant main effect of Block, $F(1,55) = 6.1$, $p = 0.02$, $\eta_p^2 = 0.10$. This decrease in responding across block was presumably due to habituation in skin conductance across fear acquisition training. However, this decrease in responding between blocks did not lead to a significant interaction between CS type and Block, $F(1,55) = 0.5$, $p = 0.5$, $\eta_p^2 < 0.01$. Similar to the expectancy data, no interaction involving Group were found, (highest $F = 0.4$, $p = 0.5$). To confirm differential responding to the CSs at the end of fear acquisition training in both groups, skin conductance responding to the CSs was compared in the second block across groups. Responses to CS+ were significantly larger than to CS-, $F(1,55) = 16.0$, $p < 0.01$, $\eta_p^2 = 0.23$. No other effects reached significance (highest $F = 1.8$, $p = 0.2$). Collectively, both groups showed elevated SCRs to the CS+ compared to the CS- without group differences, indicating successful acquisition of differential SCRs in both groups.

2.2. Avoidance test

Fig. 3 shows the proportion of low-reward option choices across the three test blocks. Critically, the low-reward option was more frequently chosen by the Generalization group compared to the Control group, $F(1,55) = 12.1$, $p < 0.01$, $\eta_p^2 = 0.18$. In other words, participants in the Generalization group were more likely to avoid choosing the high-reward option than those in the Control group. Furthermore, the Generalization group showed a decline in choosing the low-reward option, while an opposite pattern was observed in the Control group, confirmed by a significant interaction between Group and Block, $F(1,55) = 7.4$, $p < 0.01$, $\eta_p^2 = 0.12$. Follow-up analyses revealed a significant increase in choosing the low-reward option over blocks in the Control group, $F(1,55) = 5.0$, $p = 0.03$, $\eta_p^2 = 0.15$. In contrast, the decrease in frequency of choosing the low-reward option in the Generalization group was not significant, $F(1,55) = 3.1$, $p = 0.09$, $\eta_p^2 = 0.10$. An additional analysis was carried out to examine whether the groups were responding at chance level. This is an important check to examine whether the Control group was sensitive to the reward contingency and not responding merely at chance level. Therefore, the proportion of low-reward option in each group were tested against chance (i.e., 0.5) across all test blocks. Although responding in the Generalization group did not differ from chance, $F(1,27) = 1.2$, $p = 0.3$, $\eta_p^2 = 0.03$, the Control group responded significantly lower than chance, $F(1,28) = 21.9$, $p < 0.01$, $\eta_p^2 = 0.43$. In sum, this confirms that participants were sensitive to the reward contingency, suggesting that the difference in avoidant decisions between groups was largely due to the

Table 1
Demographic and DASS-21 data.

	Generalization group (n = 28)	Control group (n = 29)	F or χ^2	*p*	η_p^2 or Cramer's V
Age	25.1 (8.0)	27.1(10.0)	0.7	0.4	0.01
Sex - Females	22 (79%)	23 (79%)	0.005	0.9	< 0.01
US intensity	0.9 mA (0.5)	1.1 mA (0.4)	2.4	0.1	0.04
DASS 21-Anxiety	2.1 (2.9)	4.1 (4.6)	3.8	0.06	0.06
DASS 21-Depression	4.9 (5.7)	4.7 (4.7)	0.02	0.9	< 0.01
DASS 21-Stress	7.2 (5.7)	8.3 (7.4)	0.4	0.5	< 0.01

Note. Means (and standard deviations).

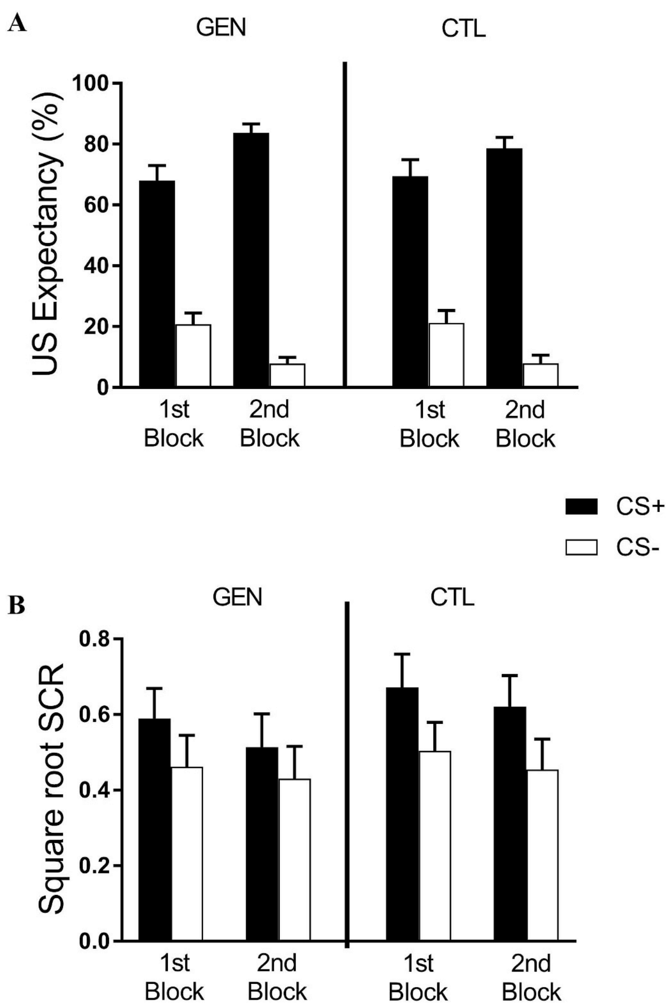

Fig. 2. (A) US expectancy ratings and (B) skin conductance responses during fear acquisition. GEN = Generalization group; CTL = Control group.

effect of generalized fear. Critically, the Control group was more likely to choose the more optimal high-reward option than the Generalization group, however, the frequency of choosing the high-reward option decreased across test.

2.3. Indicators of fear generalization during costly avoidance decisions

For each block, the averaged expectancy ratings and skin conductance responses to the stimuli after choosing the *first* high-reward option (GS+ or NS-H) were compared to the stimuli after choosing the *first* low-reward option (GS- or NS-L). This comparison tested whether fear generalized to novel stimuli that were categorically related to stimuli presented in fear acquisition training (i.e., higher responding to GS+ than to GS- in the Generalization group but similar responding to the NSs in the Control group). A total of six participants (3 in each group) had to be excluded because they only chose either high- or low-reward options for all trials in either one of the three test blocks (i.e., precluding comparison between GS/NS types).[3]

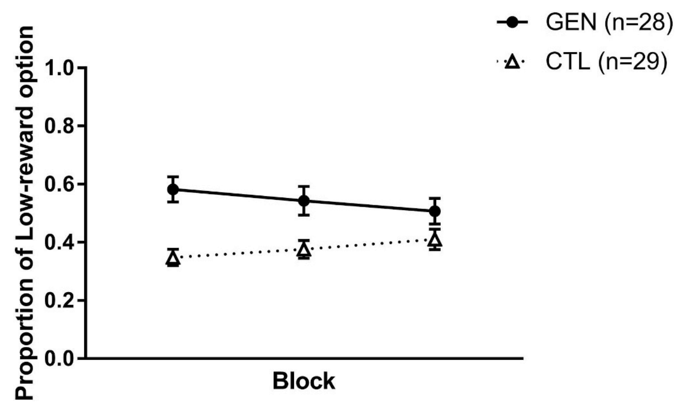

Fig. 3. Proportion of low-reward options for the Generalization and Control group across the 3 test blocks. GEN = Generalization group; CTL = Control group.

Fig. 4A shows the US expectancy ratings to the novel exemplars after choosing the first high- and low-reward option for each test block. Participants in the Generalization group showed a more significant decrease in US expectancies to stimuli across blocks compared to those in the Control group, however, this decrease was mainly driven by ratings to GS+. This pattern was confirmed by a 3-way interaction involving Group, Stimulus type and Block, $F(1,49) = 20.7, p < 0.01, \eta_p^2 = 0.30$. Follow-up analyses for each group confirmed that the decrease in ratings was more significant to GS+ than to GS- in the Generalization group, indicated by a significant interaction between Stimulus type and Block, $F(1,24) = 29.1, p < 0.01, \eta_p^2 = 0.55$, while the decrease in ratings to both NSs in the Control group was similar across blocks, $F(1,25) = 1.6, p = 0.22, \eta_p^2 = 0.06$. The Control group showed a significant main effect of Block, $F(1,25) = 6.3, p = 0.02, \eta_p^2 = 0.20$, however, the main effect of Stimulus type did not reach significance, $F(1,25) = 0.3, p = 0.59, \eta_p^2 = 0.01$. Importantly, the Generalization group showed significantly higher US expectancies to the GS+ than to the GS- compared to the ratings to NS-H than to the NS-L in the Control group, supported by a significant interaction between Group and Stimulus type, $F(1,49) = 72.7, p < 0.01, \eta_p^2 = 0.60$; follow-up analysis confirmed that the Generalization group showed significant differential ratings to the GSs, $F(1,24) = 97.1, p < 0.01, \eta_p^2 = 0.81$ while the Control group showed no significant difference in ratings to the NSs, $F(1,25) = 0.3, p = 0.6, \eta_p^2 = 0.06$. In summary, the Generalization group showed significantly higher ratings to GS+ compared to GS-, while this discriminative rating decreased across block. In contrast, the Control group showed similar ratings to both NSs, and this non-

[3] The group difference in avoidant decision remained similar to the analyses before excluding participants who chose either high- or low-reward option for all trials in either one of the three decision blocks (see Supplementary Materials).

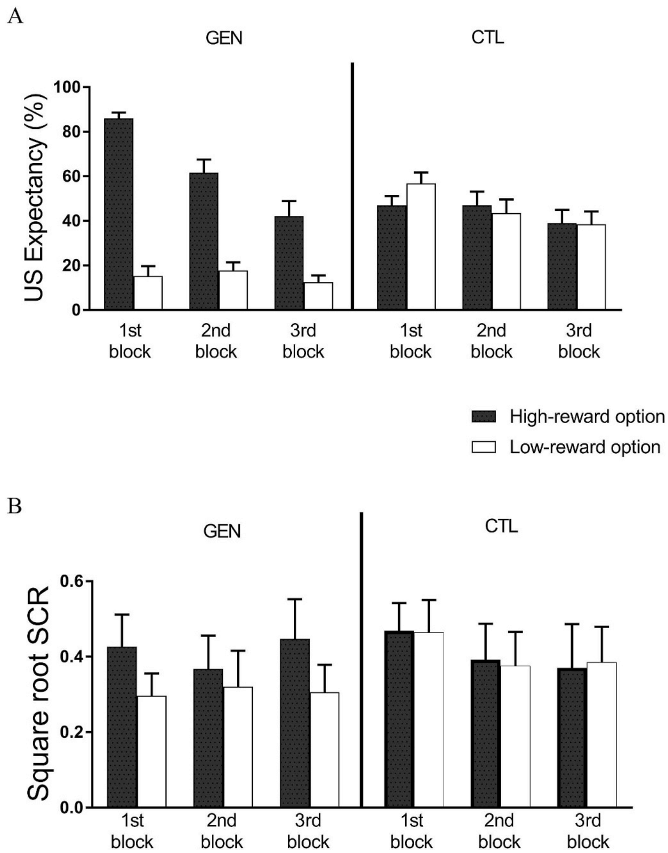

Fig. 4. (A) US expectancy ratings and (B) skin conductance responding to the stimuli following the first high- and low-reward option in each test block. GEN = Generalization group; CTL = Control group.

differential rating between stimuli decreased slower than that in the Generalization group across blocks.

Fig. 4B shows the skin conductance responding to the novel exemplars in each test block. No main effects reached significance (highest F = 3.5, p = 0.07). Although the Generalization group seemed to show differential skin conductance responding to stimuli following the high- and low-reward option while responding to stimuli following both options were highly similar in the Control group, the interaction between Group and Stimulus type did not reach significance, $F(1,49) = 3.3$, $p = 0.08$, $\eta_p^2 = 0.06$. No other effects reached significance (highest F = 0.9, p = 0.4).

2.4. Post-hoc check of actual reward contingencies in each group

To assess whether choosing the high-reward option actually led to more reward than the low-reward option, we carried out a post-hoc check to examine the actual reward contingencies in each group. For the Generalization group, choosing the high-reward option led to a 63.0% reward reinforcement rate, while the low-reward option led to a 38.7% reward reinforcement rate. Similarly, the Control group showed a reward reinforcement rate of 61.2% for the high-reward option and a 39.9% reinforcement rate for the low-reward option. In sum, the actual reward contingencies were close to the 60%–40% contingencies, in which the high-reward option led to higher payoff. This further supported the notion that choosing the low-reward option can be used as an index of costly avoidance.

3. Discussion

The current study examined whether acquired fear, which generalizes to categorically-related stimuli, triggers costly avoidance. Participants in the Generalization group chose between a high-reward option linked to categorical fear stimuli and a low-reward option linked to categorical safety stimuli. In contrast, high- and low-reward options were linked to stimuli of fear-irrelevant categories in the Control group. Main findings indicated successful acquisition of fear and its generalization to behavioral decision. In the Generalization group, participants showed higher US expectancies to the GS+ compared to the GS-. This suggests that conditioned fear to the CS+ exemplars generalized to the novel GS+ exemplars because of their shared categorical membership. Similarly, safety learning to the CS- exemplars also generalized to the GS- exemplars despite their novelty. Although a similar pattern was descriptively observed in the skin conductance data, it was not statistically supported. Furthermore, US expectancies to the GS+ exemplars decreased across test due to fear extinction, since no US was administered during test. The current findings align with previous studies where conditioned fear and safety learning generalize to novel stimuli that are categorically related to the CS+ and CS- respectively (Dunsmoor et al., 2014, 2012; Meudlers, Vandael & Vlaeyen, 2016; Vervoort et al., 2014). The present findings extend these studies by demonstrating categorical generalization of fear to instrumental avoidance. Taken together, acquired fear generalized to categorically-related stimuli and triggered costly behavioral avoidance.

In the Control group, participants showed similar US expectancies to all novel stimuli. (i.e., NS-H and NS-L). This suggests neither fear nor safety learning to the CS exemplars had generalized to these fear-irrelevant novel stimuli. Interestingly, US expectancies to the NS exemplars were approximately at chance (i.e., 50%). This was presumably due to an ambiguity effect since the NS exemplars were not categorically related to any CS exemplars, which render their threat value ambiguous during their first presentation. Furthermore, the decrease in US expectancies to the NS exemplars was not as rapid as those to the GS + exemplars. This was again potentially due to the aforementioned ambiguity effect as in each block a novel NS exemplar was presented. Ambiguity about the threat value of the novel NSs only mildly decrease, thereby yielding the uncertain US expectancies (approximately 50% US occurrence). Importantly, US expectancy did not differ between the stimuli of the two novel NS categories. This suggests that behavioral approach to either option was not affected by previous experience of acquired fear. In sum, these results demonstrate that fear and safety learning generalized to categorical fear stimuli and categorical safety stimuli respectively, but did not generalize to stimuli of fear irrelevant categories.

Critically, categorical fear generalization was linked to behavioral decisions. Participants in the Generalization group were less likely to choose the high-reward option compared to the Control group. This pattern indicates costly fear avoidance, since participants avoided choosing the optimal option that led to higher chance of reward. This effect was due to fear generalization from the CS+ category to the avoidance test, since the high-reward option in the Generalization group was always followed by a novel exemplar that belonged to the fear-related (CS+) category. Avoidance was considered costly for two reasons. First, a post-hoc analysis confirmed that choosing the high-reward option led to better payoff, suggesting that avoiding the high-reward option was costly (i.e., costly avoidance). Second, the novel GS + posed no actual threat, rendered avoidance unnecessary (see Lissek et al., 2010, 2014). The current findings align with previous studies that found fear avoidance to novel stimuli conceptually related to CS+. For instance, Boyle et al. (2016) paired a word with an aversive US (e.g., broth; CS+) and another word with no US (e.g., assist; CS-). In the following test phase, when given an opportunity to avoid a potential US, participants were more likely to avoid novel words semantically related to CS+ (e.g., soup) than those semantically related to CS- (e.g., help). Similarly, empirical studies also found that participants tended to avoid novel stimuli that belonged to the same artificial symbolic category of CS+ than those that belonged to the same artificial symbolic category of CS- (Augustson & Dougher, 1997; Dymond et al., 2011;

2014). The current findings thus extended past research by showing that novel stimuli categorically related to the CS+ can also trigger avoidance behaviors. Moreover, past research focused on low-cost avoidance, which arguably does not assess the pathological quality of avoidance as seen in anxiety and related disorders. In the present study, categorical fear generalization triggered avoidance despite avoidance resulted in less rewards. Thus, the present study is the first to show that categorical fear generalization triggers costly avoidance.

Across the avoidance test, participants in the Generalization group showed a decreasing trend in choosing the low-reward option. This decrease in costly avoidance was presumably due to fear extinction to the GS+, since no US was delivered in test. In support, US expectancies decreased across test. However, the decrease in the frequency of choosing the low-reward option was not statistically supported. This insignificant decrease in the Generalization group could be potentially driven by participants who were more motivated to avoid fear-related stimuli rather than gaining reward. Future studies can match individual participant's motivation of avoiding fear-relevant stimuli and motivation of reward gain in order to minimize the impact of motivation discrepancy on fear extinction. In contrast, the Control group showed an increase in frequency in choosing the low-reward option across decision task. This unexpected pattern could be attributed to the threat ambiguity of the NS exemplars. The ambiguous threat value of NS exemplars may have motivated participants to explore both high- and low-reward options to check which option is the safest. One may argue that the level of threat ambiguity should attenuate after the first test block, therefore the Control group should have stopped exploring between options. However, given that new NS exemplars were presented in each block, threat ambiguity of these NS exemplars may reinitiated the exploratory approach. This interpretation aligned with two patterns observed in the expectancy data in the Control group. First, there was little to no extinction learning to the NS exemplars across test blocks, suggesting that the level of threat ambiguity of the NS exemplars remained relatively stable across test. Second, there were no differential ratings between the NS-H and NS-L options, suggesting that they had similar levels of threat ambiguity. Furthermore, the Control group may have a shifted motivation from optimal choices to exploration of threat ambiguity. That is, the effect of threat ambiguity may have overpowered participants' intrinsic motivation to gain more reward, leading them to explore between options instead of continue choosing the high-reward option.

The current findings suggest categorical fear generalization as a pathway of the development of pathological avoidance. Once fear is acquired to certain stimuli, it would spread to other categorically-related, innocuous stimuli, which in turn triggers costly avoidance. Preliminary evidence has suggested that anxiety disorder individuals show excessive perceptual generalization of fear (Kaczkurkin et al., 2017; Lissek et al., 2014, 2010). It remains speculative whether individuals with anxiety disorder would also show broader fear generalization among categories. However, if this is the case, the present findings would suggest that costly avoidance can be triggered by a wide range of stimuli that are categorically related to the fear-related stimuli, leading to excessive pathological avoidance. Another link to anxious psychopathology may be that clinially anxious individuals do not show elevated categorical generalization, but show stronger avoidance in response to generalized fear. In support, Pittig et al. (2014) showed that trait anxious individuals showed elevated costly avoidance to CS+ despite they showed similar level of fear responding to CS+ to low anxious individuals. Future studies can examine whether individuals with anxiety disorder show stronger categorical fear generalization, elevated costly avoidance in response to generalized fear, or both.

In terms of clinical implications, the decrease in US expectancies to GS+ across test suggests that generalized fear would decrease once individuals have directly experience that these stimuli are not followed by any aversive outcomes (see protection from extinction, Lovibond et al., 2009). This suggests exposure-based therapies can effectively reduce fear to fear-related stimuli. In addition, the reward may have acted as an incentive for an individual to approach the fear-related stimuli, decreasing the chance of avoiding the stimuli which may lead to protection from extinction. In support, positive outcomes have been found to reduce safety behavior and thereby alleviate protection from extinction (Pittig, 2019). This suggests that therapies can emphasize on the advantage of confronting or approaching a fear-related stimulus or situation.

One limitation of this study was that categorical fear generalization was not significant in the skin conductance data. Importantly, this was not due to a failure of fear acquisition in skin conductance, since participants showed differential responding to the CSs in the last block of fear acquisition training. One reason for the insignificant findings may be the large inter-individual variability of skin conductance (Lykken & Venables, 1971; Wong & Lovibond, 2018). However, we still observed similar descriptive patterns in expectancy and skin conductance data. Another limitation was the usage of hypothetical reward instead of real reward. One may argue that using a hypothetical reward may not be rewarding enough to promote behavioral non-avoidance, therefore not being able to fully capture the group differences in the behavioral data. However, past studies have used hypothetical rewards and successfully motivated behavioral non-avoidance (e.g., Dibbets & Fonteyne, 2015; Pittig, 2019; Pittig et al., 2014, 2018), and even behavioral approach (Pittig & Dehler, 2019). Furthermore, studies have shown that both hypothetical and real rewards had a similar effect on decision-making tasks (Bickel, Picock, Yi & Angtuaco, 2009; Bowman & Turnbull, 2003; Jenkinson, Baker, Edelstyn, & Ellis, 2008; Locey, Jones, & Rachlin, 2011; Madden et al., 2004).

In conclusion, the present study replicated the finding of conceptual fear generalization in humans (Dunsmoor, Martin, & LaBar, 2012; 2014; Meulders et al., 2017; Vervoort et al., 2014; Wong & Lovibond, accepted) and expands these findings to generalization stimuli included in an instrumental decision task. Importantly, it demonstrates that generalized fear to novel stimuli that were categorically related to the fear stimuli triggers costly avoidance. Therefore the current study arguably provides a laboratory model to examine avoidance responses to fear generalization stimuli, which more closely resemble maladaptive pathological avoidance in anxiety disorders.

CRediT authorship contribution statement

Alex H.K. Wong: Conceptualization, Formal analysis, Investigation, Methodology, Writing - original draft, Visualization, Software. **Andre Pittig:** Conceptualization, Funding acquisition, Methodology, Writing - review & editing, Software, Supervision.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2020.103606.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)*. Arlington, VA: American Psychiatric Publishing.

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*, 176–181. https://doi.org/10.1037/1040-3590.10.2.176.

Augustson, E. M., & Dougher, M. J. (1997). The transfer of avoidance evoking functions through stimulus equivalence classes. *Journal of Behavior Therapy and Experimental Psychiatry, 3*, 181–191. https://doi.org/10.1016/S0005-7916(97)00008-6.

Barlow, D. H. (2002). *Anxiety and its disorders: The nature and treatment of anxiety and panic* (2nd ed.). New York, NY: Guilford Press.

Bennett, M., Vervoort, E., Boddez, Y., Hermans, D., & Baeyens, F. (2015). Perceptual and conceptual similarities facilitate the generalization of instructed fear. *Journal of Behavior Therapy and Experimental Psychiatry, 48*, 149–155. https://doi.org/10.1016/j.jbtep.2015.03.011.

Bickel, W. K., Pitcock, J. A., Yi, R., & Antuaco, E. J. (2009). Congruence of BOLD response across intertemporal choice conditions: Fictive and real money gains and losses. *Journal of Neuroscience, 29*(27), 8839–8846. https://doi.org/10.1523/JNEUROSCI.5319-08.2009.

Boucsein, W., Fowles, D. C., Grimnes, S., et al. (2012). Publication recommendations for electrodermal measurements. *Psychophysiology, 49*(8), 1017–1034. https://doi.org/10.1111/j.1469-8986.2012.01384.x.

Bowman, C. H., & Turnbull, O. H. (2003). Real versus facsimile reinforcers on the Iowa gambling task. *Brain and Cognition, 53*, 207–210. https://doi.org/10.1016/S0278-2626(03)00111-8.

Boyle, S., Roche, B., Dymond, S., & Hermans, D. (2016). Generalisation of fear and avoidance along a semantic continuum. *Cognition & Emotion, 30*(2), 340–352. https://doi.org/10.1080/02699931.2014.1000831.

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*, 79–89. https://doi.org/10.1016/S0005-7967(96)00068-X.

Bublatzky, D., Alpers, G. W., & Pittig, A. (2017). From avoidance to approach: The influence of threat-of-shock on reward-based decision making. *Behaviour Research and Therapy, 96*, 47–56. https://doi.org/10.1016/j.brat.2017.01.003.

Chan, C. K. J., & Harris, J. A. (2019). The partial reinforcement extinction effect: The proportion of trials reinforced during conditioning predicts the number of trials to extinction. *Journal of Experimental Psychology: Animal Learning and Cognition, 45*(1), 43–58. https://doi.org/10.1037/xan0000190.

Craske, M. G. (1999). *Anxiety disorders: Psychological approaches to theory and treatment.* Boulder, CO: Westview Press.

Dibbets, P., & Fonteyne, R. (2015). High spider fearfuls can overcome their fear in a virtual approach-avoidance conflict task. *Journal of Depression & Anxiety, 4*(2), https://doi.org/10.4172/2167-1044.1000182.

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

Dunsmoor, J. E., & Murphy, G. L. (2014). Stimulus typicality determines how broadly fear is generalized. *Psychological Science, 25*(9), 1816–1821. https://doi.org/10.1177/0956797614535401.

Dunsmoor, J. E., & Murphy, G. L. (2015). Categories, concepts, and conditioning: How humans generalize fear. *Trends in Cognitive Sciences, 19*(2), 73–77. https://doi.org/10.1016/j.tics.2014.12.003.

Dymond, S., Dunsmoor, J. E., Vervliet, B., Roche, B., & Hermans, D. (2015). Fear generalization in humans: Systematic review and implications for anxiety disorder research. *Behavior Therapy, 46*, 561–582. https://doi.org/10.1016/j.beth.2014.10.001.

Dymond, S., & Roche, B. (2009). A contemporary behavior analysis of anxiety and avoidance. *The Behavior Analyst, 32*, 7–27.

Dymond, S., Schlund, M. W., Roche, B., De Houwer, J., & Freegard, G. P. (2012). Safe from harm: Learned, instructed, and symbolic generalization pathways of human threat- avoidance. *PloS One, 7*(10), e47539. https://doi.org/10.1371/journal.pone.0047539.

Dymond, S., Schlund, M. W., Roche, B., & Whelan, R. (2014). The spread of fear: Symbolic generalization mediates graded threat-avoidance in specific phobia. *Quarterly Journal of Experimental Psychology, 67*, 247–259. https://doi.org/10.1080/17470218.2013.800124.

Dymond, S., Schlund, M., Roche, B., Whelan, R., Richards, J., & Davies, C. (2011). Inferred threat and safety: Symbolic generalization of human avoidance learning. *Behaviour Research and Therapy, 49*, 614–621. https://doi.org/10.1016/j.brat.2011.06.007.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175–191.

Henry, J. D., & Crawford, J. R. (2005). The short-form version of the Depression Anxiety Scales (DASS-21): Construct validity and normative data in a large non-clinical sample. *British Journal of Clinical Psychology, 44*, 227–239. https://doi.org/10.1348/014466505X29657.

Humphreys, L. G. (1939). The effect of random alternation of reinforcement on the acquisition and extinction of conditioned eyelid reactions. *Journal of Experimental Psychology, 25*(2), 141–158. https://doi.org/10.1037/h0058138.

Jenkinson, P. M., Baker, S. R., Edelstyn, N. M. J., & Ellis, S. J. (2008). Does autonomic arousal distinguish good and bad decisions? *Journal of Psychophysiology, 22*, 141–149. https://doi.org/10.1027/0269-8803.22.3.141.

Kaczkurkin, A. N., Burton, P. C., Chazin, S. M., Manbeck, A. B., Espen-Sturges, T., Cooper, S. E., et al. (2017). Neural substrates of overgeneralized conditioned fear in PTSD. *American Journal of Psychiatry, 174*(2), 125–134. https://doi.org/10.1176/appi.ajp.2016.15121549.

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.* https://doi.org/10.1037/xlm0000558.

Lissek, S., Kaczkurkin, A. N., Rabin, S., Geraci, M., Pine, D. S., & Grillon, C. (2014). Generalized anxiety disorder is associated with over-generalization of classically conditioned fear. *Biological Psychiatry, 75*, 909–915. https://doi.org/10.1016/j.biopsych.2013.07.025.

Lissek, S., Rabin, S., Heller, R. E., Lukenbaugh, D., Geraci, M., Pine, D. S., et al. (2010). Overgeneralization of conditioned fear as a pathogenic marker of panic disorder. *American Journal of Psychiatry, 167*, 47–55. https://doi.org/10.1176/appi.ajp.2009.09030410.

Livesey, E. J., & McLaren, I. P. L. (2009). Discrimination and generalization along a simple dimension: Peak shift and rule-governed responding. *Journal of Experimental Psychology: Animal Behavior Processes, 35*(4), 554–565. https://doi.org/10.1037/a0015524.

Locey, M. L., Jones, B. A., & Rachlin, H. (2011). Real and hypothetical rewards in self-control and social discounting. *Judgment and Decision Making, 6*, 522–564.

Lovibond, P. F. (1998). Long-term stability of depression, anxiety, and stress syndromes. *Journal of Abnormal Psychology, 107*, 520–526. https://doi.org/10.1037/0021-843X.107.3.520.

Lovibond, S. H., & Lovibond, P. F. (1995). *Manual for the depression anxiety stress scales (2nd ed.).* Sydney Psychology Foundation.

Lovibond, P. F., Mitchell, C. J., Minard, E., Brady, A., & Menzies, R. G. (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.

Lovibond, P. F., Saunders, C., Weidemann, G., & Mitchell, C. J. (2008). Evidence for expectancy as a mediator of avoidance and anxiety in a laboratory model of human avoidance learning. *The Quarterly Journal of Experimental Psychology, 61*(8), 1199–1216. https://doi.org/10.1080/17470210701503229.

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.

Madden, G. J., Raiff, B. R., Lagorio, C. H., Begotka, A. M., Mueller, A. M., Hehli, D. J., et al. (2004). Delay discounting of potentially real and hypothetical rewards: II. Between- and within-subject comparisons. *Experimental and Clinical Psychopharmacology, 12*(4), 251–261. https://doi.org/10.1037/1064-1297.12.4.251.

Mendlowicz, M. V., & Stein, M. B. (2000). Quality of life in individuals with anxiety disorders. *American Journal of Psychiatry, 157*, 669–682. https://doi.org/10.1176/appi.ajp.157.5.669.

Meulders, A., Franssen, M., Fonteyne, R., & Vlaeyen, J. (2016). Acquisition and extinction of operant pain-related avoidance behavior using a 3 degress-of-freedom robotic arm. *Pain, 157*(5), 1094–1104. https://doi.org/10.1097/j.pain.0000000000000483.

Meulders, A., Vandael, K., & Vlaeyen, J. W. S. (2017). Generalization of pain-related fear based on conceptual knowledge. *Behavior Therapy, 48*(3), 295–310. https://doi.org/10.1016/j.beth.2016.11.014.

Neurobehavioral Systems, Inc., Berkeley, CA.

Nilges, P., & Essau, C. (2015). Die depressions-angst-stress-skalen: Der DASS–ein screeningverfahren nicht nur für schmerzpatienten [depression, anxiety and stress scales: DASS–A screening procedure not only for pain patients]. *Schmerz, Der, 29*(6), 649–657. https://doi.org/10.1007/s00482-015-0019-z.

Olatunji, B. O., Cisler, J. M., & Tolin, D. F. (2007). Quality of life in the anxiety disorders: A meta-analytic review. *Clinical Psychology Review, 27*, 572–581. https://doi.org/10.1016/j.cpr.2007.01.015.

Parsons, R. G., & Ressler, K. J. (2013). Implications of memory modulation for post-traumatic stress and fear disorders. *Nature Neuroscience, 16*(2), 146–153. https://doi.org/10.1038/nn.3296.

Pineles, S. L., Orr, M., & Orr, S. P. (2009). An alternative scoring method for skin conductance responding in a differential fear conditioning paradigm with a long- duration conditioned stimulus. *Psychophysiology, 46*(5), 984–995. https://doi.org/10.1111/j.1469-8986.2009.00852.x.

Pittig, A. (2019). Incentive-based extinction of safety behaviors: Positive outcomes competing with aversive events trigger fear-opposite action and prevent protection from fear extinction. *Behaviour Research and Therapy, 121*, 103463. https://doi.org/10.1016/j.brat.2019.103463.

Pittig, A., & Dehler, J. (2019). Same fear response, less avoidance: Rewards competing with aversive outcomes do not buffer fear acquisition, but attenuate avoidance to accelerate subsequent fear extinction. *Behaviour Research and Therapy, 112*, 1–11. https://doi.org/10.1016/j.brat.2018.11.003.

Pittig, A., Hengen, K. M., Bublatzky, F., & Alpers, G. W. (2018a). Social and monetary incentives counteract fear-driven avoidance: Evidence from approach-avoidance decisions. *Journal of Behavior Therapy and Experimental Psychiatry, 60*, 69–77. https://doi.org/10.1016/j.jbtep.2018.04.002.

Pittig, A., & Scherbaum, S. (2020). Costly avoidance in anxious individuals: Elevated threat avoidance in anxious individuals under high, but not low competing rewards. *Journal of Behavior Therapy and Experimental Psychiatry*101524. https://doi.org/10.1016/j.jbtep.2019.101524.

Pittig, A., Schulz, A. R., Craske, M. G., & Alpers, G. W. (2014). Acquisition of behavioral avoidance: Task-irrelevant conditioned stimuli trigger costly decisions. *Journal of Abnormal Psychology, 123*(2), 314–329. https://doi.org/10.1037/a0036136.

Pittig, A., Treanor, M., LeBeau, R. T., & Craske, M. G. (2018b). 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.

Pittig, A., Wong, A. H. K., Glück, V. M., & Boschet, J. M. (2020). Avoidance and its bi-directional relationship with conditioned fear: Mechanisms, moderators, and clinical implications. *Behaviour Research and Therapy, 126*, 103550.

Rattel, J. A., Miedl, S. F., Blechert, J., & Wilhelm, F. H. (2017). Higher threat avoidance costs reduce avoidance behaviour which in turn promotes fear extinction in humans. *Behaviour Research and Therapy, 96*, 37–46. https://doi.org/10.1016/j.brat.2016.12.010.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of*

Experimental Psychology: Human Learning & Memory, 6(2), 174–215. https://doi.org/10.1037/0278-7393.6.2.174.

Thomas, D. R., Lusky, M., & Morrison, S. (1992). A comparison of generalization functions and frame of reference effects in different training paradigms. *Perception & Psychophysics, 51*(6), 529–540. https://doi.org/10.3758/BF03211650.

Van Meurs, B., Wigggert, N., Wicker, I., & Lissek, S. (2013). Maladaptive behavioral consequences of conditioned fear-generalizaiton: A pronounced, yet sparsely studied, feature of anxiety pathology. *Behaviour Research and Therapy, 57*, 29–37. https://doi.org/10.1016/j.brat.2014.03.009.

Vervliet, B., & Indekeu, E. (2015). Low-cost avoidance behaviors are resistant to fear extinction in humans. *Frontiers in Behavioral Neuroscience, 9*, 351. https://doi.org/10.3389/fnbeh.2015.00351.

Vervoort, E., Vervliet, B., Bennett, M., & Baeyens, F. (2014). Generalization of human fear a cquisition and extinction within a novel arbitrary stimulus category. *PloS One, 9*(5), e96569. https://doi.org/10.1371/journal.pone.0096569.

Vision GmbH, Gilching, G. .

Wong, A. H. K., & Lovibond, P. F. (accepted). Breakfast or bakery? The role of categorical ambiguity in over-generalization of learned fear in trait anxiety. Emotion.

Wong, A. H. K., & Lovibond, P. F. (2017). Rule-based generalisation 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 generalisation 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.