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Breakfast or Bakery? The Role of Categorical Ambiguity in Overgeneralization of Learned Fear in Trait Anxiety

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Pavlovian conditioning studies have shown that humans can generalize conditioned fear to novel stimuli that are categorically related to the threat cue, despite perceptual dissimilarities. The current work examined the role of trait anxiety in the generalization of fear to categorically related objects. Items from 1 category, breakfast or bakery, were paired with shock whereas items from the other category were not. Participants were then tested on ambiguous cross-classified items—those that fitted in both the threat and safe categories. No trait anxiety effect was found in generalization to novel stimuli that clearly belonged to either the threat or the safe category in either shock expectancy ratings or skin conductance. In contrast, trait anxious individuals showed a bias toward higher threat appraisal to the ambiguous cross-classified stimuli. However, this pattern was not due to trait anxious individuals being more likely to perceive ambiguous items as belonging to the threat category. Instead they appear to display a bias toward overestimation of threat when the threat level is ambiguous. The current findings indicate that threat ambiguity modulates the effect of trait anxiety on categorical fear generalization.

Keywords: generalization, trait anxiety, ambiguity, categorical induction, fear conditioning

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Fear conditioning has served as a well-controlled laboratory paradigm to examine the acquisition of fear to innocuous objects. After pairings between a neutral stimulus (conditioned stimulus [CS]) and an aversive stimulus, the CS comes to elicit an expectancy of the aversive outcome and triggers conditioned (anticipatory) fear responses. The process of how a previously neutral CS becomes threatening has been seen as conceptually parallel to how anxiety patients acquire maladaptive fear to innocuous objects or situations (Mineka & Zinbarg, 2006; Watson & Rayner, 1920).

Using the above framework, numerous studies have found that anxious patients display maladaptive patterns of fear learning (see Lissek et al., 2005 and Duits et al., 2015 for meta-analyses). One of these maladaptive patterns is thought to be the failure to inhibit fear responses to safety cues. After differential conditioning to a threat cue (CS+) and a safety cue (CS−), anxious patients showed more fear responding to the safety cue compared to healthy participants (e.g., Grillon & Davis, 1997; Lissek et al., 2008, 2009). These findings support the idea that anxiety disorders are associated with a failure to inhibit fear to safety cues, which is proposed to be one of the etiological pathways to elevated, maladaptive fear to threat-neutral objects or situations (Davis, Falls, & Gewirtz, 2000).

Although maladaptive fear learning has been found in patients with current anxiety disorders, this research cannot distinguish whether such a pattern is a consequence of anxiety disorders, or whether it is a vulnerability factor for their development. In addition, clinical samples introduce a great deal of comorbidity as well as sequelae of their clinical condition. Therefore, it is important to study individuals at risk of developing anxiety disorder, and examine if they show similar maladaptive patterns (Lonsdorf & Merz, 2017). Trait anxiety has been widely proposed as a risk factor for developing anxiety disorders (e.g., Chambers, Power, & Durham, 2004; Gershuny & Sher, 1998; Jorm et al., 2000). Similar to findings in the clinical population, empirical evidence has shown that individuals high in trait anxiety show more conditioned fear to safety cues than low anxious controls (e.g., Gazendam, Kamphuis, & Kindt, 2013; Grillon & Ameli, 2001; Haaker et al., 2015). This suggests that trait anxious individuals show an inability to suppress fear to safety objects or situations, similar to the clinical population.

An alternative explanation for the apparent impaired safety learning among trait anxious individuals is overgeneralization of fear. Haddad, Pritchett, Lissek, and Lau (2012) trained participants with one CS+ and two CS−s, where one CS− was perceptually similar to CS+ (i.e., similar CS−) and the other one not (i.e., dissimilar CS−). Trait anxious individuals showed a significant increase in eyeblink startle responses to the similar CS−, but not to the dissimilar CS−, while this pattern was not observed in the

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low anxious control group. This suggests that trait anxious individuals show excessive perceptual generalization of fear rather than impaired safety learning; if the latter interpretation was true, an increase in fear responding should have been observed to both safety cues. The present study aimed to extend the investigation of overgeneralization of fear learning.

Our study built on recent research showing that humans can generalize via a conceptual pathway within a Pavlovian conditioning framework. Dunsmoor, Martin, and LaBar (2012) demonstrated that conditioned fear can selectively generalize to novel cues that are categorically related to the CS+. Participants received exemplars from two categories, animals and tools. Critically, each exemplar was only presented once, rendering the presentation of each exemplar unique. Half of the exemplars from one category (e.g., animal) were reinforced by an aversive shock (i.e., 50% reinforcement rate), while exemplars from the other category (e.g., tool) were never reinforced. Overall, participants developed a significant differentiation in responding to exemplars between the two categories. That is, they showed increased shock expectancy ratings and skin conductance responses only to exemplars that belonged to the CS+ category but not to those that belonged to the CS− category.

Dunsmoor et al.'s (2012) results strongly suggest that fear generalization was operating at a conceptual level for two reasons. First, given that each exemplar was presented only once, no learning would have occurred if participants were learning on the exemplar level (e.g., cat predicts shock, hammer predicts no shock, dog predicts shock). Second, shock expectancy ratings to both categories differentiated in early trials, suggesting participants quickly learned that the categorical membership of the exemplars determined the predictiveness of shock. Subsequent research has confirmed that fear selectively generalizes to novel stimuli from the same category as CS+ but not to those from the CS− category, despite perceptual dissimilarities between stimuli within the same category (e.g., Bennett, Vervoort, Boddez, Hermans, & Baeyens, 2015; Dunsmoor & Murphy, 2014; Meulders, Vandael, & Vlaeyen, 2017; Scheveneels, Boddez, Bennett, & Hermans, 2017). Conceptual fear generalization provides a more viable explanation for the wide spread of fear to numerous objects or situations regardless of their perceptual dissimilarities. For instance, a child who was abused by a teacher may show fear of other authority figures (e.g., police) even though they do not physically resemble the original perpetrator.

In designing the present study, we took into account evidence from both the conditioning and cognitive literatures suggesting that individual difference variables like trait anxiety exert their greatest influence when situational factors are "weak" rather than "strong" (i.e., ambiguous situations; Beckers, Krypotos, Boddez, Effting, & Kindt, 2013; Boddez et al., 2012; Lissek, Pine, & Grillon, 2006). In particular, in our recent work on the role of rule induction in perceptual generalization (Wong & Lovibond, 2018), trait anxious participants who reported a clear relational rule did not differ in their generalization of conditioned fear from low anxious controls. However, trait anxious participants who failed to identify a clear rule showed overgeneralization of fear to all novel test stimuli. We interpreted this result to mean that rule induction guides generalization by allowing participants to judge the threat value of novel stimuli. In contrast, not being able to infer a clear rule renders the threat value of novel stimuli ambiguous. These findings are consistent with our earlier work with ambiguity in safety learning (Chan & Lovibond, 1996) and with the literature on cognitive interpretation bias in trait anxiety (e.g., Byrne & Eysenck, 1993; Haney, 1973; MacLeod & Cohen, 1993; Muris, Huijding, Mayer, & Hameetman, 2008; Waters, Craske, Bergman, & Treanor, 2008).

Accordingly, we sought to manipulate the level of threat ambiguity of novel exemplars within a categorical generalization design. In the cognitive literature on anxiety, one way researchers have induced ambiguity is to present a cue that has more than one meaning, usually one affectively negative and one affectively neutral (e.g., MacLeod, 1990; MacLeod & Cohen, 1993). The present studies adopted a similar strategy, based on the idea of "cross-classification" from the categorical induction literature. According to this literature, most objects belong to more than one category. For example, Stephen Hawking was a physicist, a British citizen, and a man. When these cross-classified exemplars belong to categories that have conflicting properties, the determination of exemplar properties often becomes ambiguous (Hayes, Kurniawan, & Newell, 2011; Murphy & Ross, 1999). We hypothesized that trait anxious individuals would show a bias toward higher threat appraisal when exposed to cross-classified exemplars that could be fit into both CS+ and CS− categories (see Eysenck, MacLeod, & Mathews, 1987; MacLeod & Cohen, 1993), hence making their threat value ambiguous. Conversely, we expected that both high and low anxious individuals would show a similar degree of fear generalization to novel exemplars that clearly belonged to either the CS+ or CS− category, since their threat value would be relatively unambiguous.

Experiment 1

Exemplars from two categories, breakfast foods and bakery foods, were presented as stimuli in Experiment 1. These categories were used because of the availability of items that could readily be cross-classified (e.g., croissants; Murphy & Ross, 1999). During fear conditioning, exemplars from one category (e.g., breakfast) were paired with shock, while exemplars from the other category (e.g., bakery) were never paired with shock. In the following test phase, novel exemplars of the CS+ category and novel exemplars of the CS− category were presented. In addition, ambiguous cross-classified exemplars that fitted in both CS+ and CS− categories were presented. Novel food exemplars that were neither breakfast nor bakery items were also presented. We hypothesized that these unclassified items would have low excitatory or inhibitory strength since they belonged to neither the CS+ nor the CS− category, hence providing a control for baseline responding to novel, supposedly threat-neutral stimuli. However, they may be perceived as ambiguously threatening due to their unknown threat value, though not to the same extent as the cross-classified items.

We used a conventional fear conditioning procedure in which neutral CSs were paired with the presence or absence of an electric shock, and fear responses were assessed by recording self-reported shock expectancy and anticipatory skin conductance responses on each trial (see Lonsdorf et al., 2017). We included skin conductance as a nonspecific measure of arousal that can be interpreted as reflecting fear when other sources of arousal (such as reward or novelty) are controlled for, as they are in the differential conditioning designs we used. We assessed threat expectancy on a trial-by-trial basis as a sensitive measure of cognitive threat appraisal (Boddez et al., 2013). These two measures are thought to reflect independent fear systems by some researchers (e.g., LeDoux, 2014; Öhman & Mineka, 2001). We treated them as different components of an integrated fear system, but we were alert to the possibility of differences between them in our analyses.

Method

Participants. Undergraduates were recruited as participants who received course credit or AUD $15 for participation. Participants were prescreened by the DASS-21 (Lovibond & Lovibond, 1995). The DASS-21 is a short version of the original DASS (Depression Anxiety Stress Scales), designed to measure 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 16 or above were assigned to the high anxious group (HA group), while those with a DASS anxiety score of 4 or below were assigned to the low anxious group (LA group). According to the manual for the DASS (Lovibond & Lovibond, 1995), participants in the HA group were defined as "severely anxious" while those in the LA group were defined as "normal". Based on our previous study examining the effect of trait anxiety on fear generalization (Wong & Lovibond, 2018), we expected a medium to large effect size for the influence of trait anxiety on responding to ambiguous cues. In order to obtain 80% power to detect such an effect size, a minimum of 54 participants was required. We aimed to recruit a total of 70 participants, with 35 in each group. The experimental procedure was approved by the Human Research Ethics Committee at the University of New South Wales.

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 equipped with Matlab software (with Psychophysics Toolbox extensions; Brainard, 1997; MathWorks, 2014) generated the stimuli presented to the participants and recorded shock expectancy ratings. Another computer controlled ADInstruments equipment to record the skin conductance data via GRASS silver disk electrodes at a sampling rate of 1,000 Hz throughout the experiment.

Six breakfast exemplars (pictures of bacon, cornflake, hashbrown, oatmeal, pancakes, and pan-fried eggs), six bakery exemplars (apple & walnut log, cupcake, finger bun, garlic bread, hamburger bun, and maple Danish), and three cross-classified exemplars (croissant, English muffin, and toast) were used. These exemplars had been rated for typicality of category members by 26 participants (a priori power analysis indicated a minimum sample of 24 to provide 80% power to detect a medium effect size) in a validation task, using a Likert scale from 1 (*not at all typical*) to 7 (*highly typical*). The breakfast exemplars were rated as highly typical breakfast items (M = 6.4, SD = 1.0) but as nontypical bakery items (M = 1.9, SD = 1.5). Similarly, the bakery exemplars were rated as highly typical bakery items (M = 5.9, SD = 1.3) but as nontypical breakfast items (M = 2.9, SD = 1.5). As such, breakfast typicality ratings to the breakfast exemplars were significantly higher than the bakery typicality ratings to the same exemplars, while an opposite pattern was observed in the ratings to the bakery exemplars, confirmed by a significant interaction, $F(1, 25) = 329.6$, $p < .01$, $\eta_p^2 = 0.93$, 95% CI [2.5, 3.2]. Four of these exemplars from each category served as CSs, while the remaining two exemplars from each category served as the novel generalization stimuli (GENs) in test. The cross-classified exemplars (CC) were rated as highly typical of both breakfast (M = 6.3, SD = 1.1) and bakery (M = 5.9, SD = 1.5) categories. Two food exemplars that were neither breakfast nor bakery items (spaghetti and steak) were included as unclassified items (UC). An additional 12 breakfast and 12 bakery pictures were used in a categorical task prior to conditioning. All stimuli were colored pictures, 10 cm × 8 cm in size and were presented in the center of a white background on the computer screen.

The physical shock was a 0.5-s sinusoidal pulse electric shock (80 Hz) delivered through two stainless steel electrodes attached to the distal and middle segments of the index finger of participants' nondominant hand. Skin conductance electrodes were attached to the distal and proximal segments of the third finger of the same hand. A semicircular dial with a rotary pointer was attached to the table in front of the participants. The dial was labeled *Expectancy of shock after picture*, with the left position labeled *Certain NO SHOCK* and the right position labeled *Certain SHOCK*.

Procedure. Shock electrodes and skin conductance electrodes were attached to participants' fingers, and they were led through a work-up procedure in which they selected a level of shock that was "definitely uncomfortable but not painful." Isotonic gel was squeezed into the GRASS silver disk electrodes to maximize the sensitivity of skin conductance measure, and then attached to participants' fingers. Participants were then taken into the experimental room. As shown in Figure 1, the experiment consisted of a categorical task, followed by an acquisition phase and a test phase. Before the experiment started, headphones were placed on participants. White noise was presented throughout the experiment for noise cancellation.

Categorical task. This task was carried out prior to conditioning for three reasons. First, categorizing items into the breakfast or bakery categories was expected to increase the salience of these two categories in the subsequent conditioning task. This encouraged participants to consider both categories when making inferences (Murphy & Ross, 1999). In particular, participants would be more likely to have both breakfast and bakery categories in mind when they were shown cross-classified items, rather than merely perceiving them as either breakfast or bakery items. Second, we expected that the increased salience of both breakfast and bakery categories would facilitate learning of the category–shock associations in the subsequent conditioning task. This was intended to minimize the likelihood that participants would learn unrelated categories during fear acquisition—for instance, that unhealthy foods predict shock while healthy foods predict no shock. Third, we found that the CS+ category overshadowed the CS− category in a pilot study. That is, participants tended to learn that one category predicted shock (e.g., breakfast), while all items that did not belong to this particular category predicted no shock (e.g., everything except breakfast items predict no shock). This type of learning may have attenuated the ambiguity of cross-classified items, as participants would only perceive them as belonging to the CS+ category.

The categorical task consisted of the presentation of 12 breakfast items and 12 bakery items. Some of these items were the same

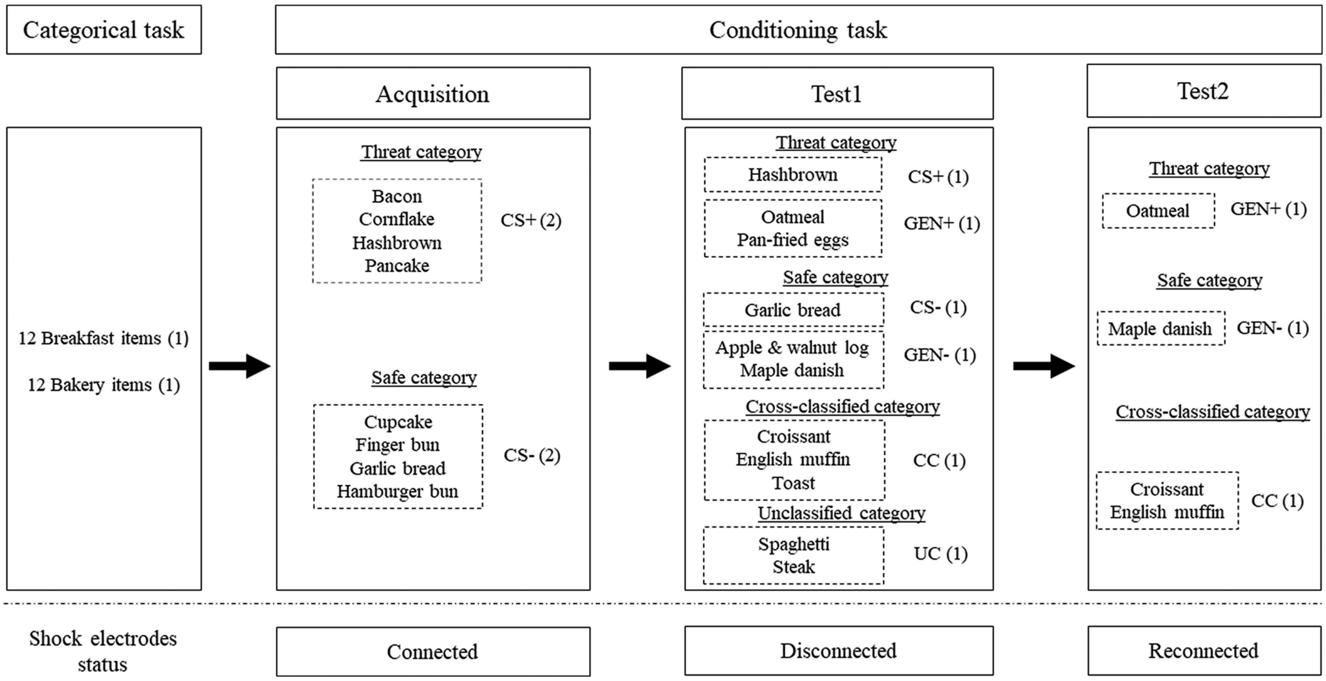

Figure 1. Experimental designs for both Experiments 1 and 2. In this illustration, the CS+ category consists of breakfast items and the CS− category consists of bakery items. Number in parentheses indicate the number of trials of that trial type. CS+ indicates reinforced exemplars; CS− indicates nonreinforced exemplars; GEN+ indicates exemplars that were in the same category as CS+; GEN− indicates exemplars that were in the same category as CS−; CC indicates cross-classified exemplars; UC indicates unclassified food items that did not fit in either category. Only CS+ exemplars in acquisition were reinforced.

as those that were presented in the subsequent conditioning task, but the specific pictures were different. The pictures were presented once in a random order. For each trial, the picture appeared at the center of the screen, with the word *breakfast* appearing on the bottom left of the screen and the word *bakery* appearing on the bottom right of the screen. Participants were instructed to categorize the picture shown by either pressing the left arrow key for breakfast or the right arrow key for bakery. No cross-classified items were shown in this task.

Acquisition (shock electrodes connected). Participants were informed that different pictures would be presented on the computer screen, which may or may not be followed by a shock. They were asked to learn the relationship between the pictures and shock. Participants were then instructed to use the dial to indicate their expectancy of shock whenever a picture appeared. The acquisition phase was divided into two blocks: in each block, four different breakfast exemplars and four different bakery exemplars served as the CSs, and were presented once each, leading to eight trials per block. All CS+s were followed by shock on every trial (100% reinforcement), while the CS−s were never reinforced. The categories that served as CS+ and CS− were counterbalanced across participants. The presentation order was pseudorandomized so that the same trial type never appeared more than twice in a row. The trial structure was made up by a 10-s baseline period, followed by 10-s stimulus presentation. If scheduled, the electric shock was presented during the last 0.5 s of CS+ presentations and coterminated with the CS.

Similar to previous fear conditioning studies in our lab (Lee, Hayes, & Lovibond, 2018; Wong & Lovibond, 2017, 2018), the test phase was divided into two stages, Test 1 and Test 2. The shock electrodes were disconnected in the former and reconnected in the latter.

Test 1 (shock electrodes disconnected). Immediately after acquisition, the experimenter paused the program and went into the experimental room. Participants were informed that due to ethical restrictions, the number of shocks was limited, hence setting up the cover story for disconnecting the shock electrodes. Although no shock could physically be delivered, participants were explicitly asked to continue making their expectancy ratings, assuming hypothetically that it was still possible for them to receive a shock. This procedure is conceptually equivalent to the "missing data procedure," which is used to minimize the impact of extinction during testing in causal judgment and prediction tasks (e.g., Shanks & Darby, 1998). This procedure also reduced the likelihood that participants would modify their response strategy due to confusion instigated by extinction. In this stage, one CS+ and CS− were randomly chosen and shown once each. Two novel generalization stimuli of the CS+ category (GEN+) and two novel stimuli of the CS− category (GEN−) were also presented once each. The three cross-classified items (CC) and the two unclassified stimuli (UC) that were neither breakfast nor bakery items were also presented once each, leading to a total of 11 trials in this stage. The stimuli were presented in a randomized order, and the trial structure followed acquisition with the exception that no electric shock was delivered.

Test 2 (shock electrodes reconnected). The experimenter reconnected the shock electrodes and participants were told that it was again possible to receive shock. This stage was included so that skin conductance responses to the test stimuli could be collected. In fact, no electric shocks were presented. One GEN+ and one GEN−, randomly chosen from Test 1, were presented. Two CC exemplars, croissant and English muffin, were also presented. These two stimuli were chosen because their breakfast typicality ratings were highly similar to their bakery typicality ratings compared to toast. In order to minimize extinction, we needed to restrict the number of stimuli tested. Therefore, we only included the four trial types described above, and omitted the CSs and UC items. The order of presentation was random.

When the conditioning task was completed, participants were asked to fill in a two-page questionnaire. On the first page, participants were asked to write down in detail how they predicted whether a picture would be followed by a shock, and also how they predicted whether a picture would not be followed by a shock. The second page was administered only after the first page was completed, and consisted of five statements. Each statement described a relationship between the pictures and the shock (breakfast predicts shock; bakery predicts shock; CC items predict shock; food items that were neither breakfast nor bakery predict shock; other). Each statement was followed by a visual analogue scale from 0 to 100%, where the left extreme was labeled *False* and the right extreme was labeled *True*.

Scoring and analysis. Although expectancy ratings were recorded in both Test 1 and Test 2, only those in Test 1 were used for data analyses as they were not affected by extinction learning. For the skin conductance measure, analysis was based on the data collected when the shock electrodes were attached (Acquisition and Test 2), since these were the phases when participants were instructed that they would receive shock, and so anticipatory anxiety was expected to occur. A low-pass 50 Hz digital filter was applied to the skin conductance data to avoid aliasing. The raw skin conductance data were then log transformed to minimize individual differences. Skin conductance scores for each trial were calculated as the difference between the mean of log skin conductance level (SCL) during the 10-s stimulus presentation and mean log SCL during the 10-s baseline period for that trial.

Planned contrasts were used to compare anxiety groups and to assess acquisition and generalization to novel test stimuli. For acquisition, the second block was compared to the first block in both measures to examine the development of differential responding to CSs+ and CSs−. In test, the expectancy measures were compared between CSs and the novel generalization stimuli (GENs; GEN+ and GEN−) to assess categorical generalization, and also between threat and safety cues (i.e., CS+ and GEN+ compared to CS− and GEN−). The resulting interaction was also analyzed to examine whether fear generalization from CS+ to GEN+ differed from that of CS− to GEN−. The final contrast was the comparison between CC and UC exemplars, to examine whether responding to ambiguous CCs were any different from responding to novel threat-neutral stimuli that did not belong to either category. For the skin conductance measure, responding to GEN+ was compared against GEN− to assess categorical generalization. Responding to the CCs was compared to the average of the GENs, in order to assess whether the CCs were treated more like GEN+ or GEN−. Finally, all interactions between the group and repeated measures contrasts were tested to evaluate group differences in responding to test stimuli. Effect sizes and standardized 95% confidence intervals were also calculated.

Results

Statistical analyses were restricted to participants who satisfied the acquisition criterion, that is, participants who demonstrated differential conditioning in their shock expectancy ratings. Differential conditioning between CS+ and CS− was defined by an average difference of at least 30 in the last acquisition block (i.e., the last 4 trials of CS+ and the last 4 trials of CS−). The acquisition criterion was relatively lenient because previous studies have found that trait anxious individuals may show a deficit in safety learning (e.g., Andreatta & Pauli, 2017; Gazendam et al., 2013). A total of four participants (3 in HA group and 1 in LA group) were excluded based on this criterion. Interestingly, all four participants responded in the postexperimental questionnaire that they had learnt the predictiveness of shock based on other categorical memberships, for instance, savory foods predict shock while sweet foods predict no shock. Most importantly, all participants who met the acquisition criterion had learnt the correct categorical memberships according to their responses in the questionnaire; hence the ambiguity of the CCs was presumed to have been established. Two participants in the LA group were excluded as they did not provide shock expectancy ratings for at least two stimuli in Test 1. Furthermore, two participants (one in each group) became suspicious about the study aim, as they asked the experimenter how they should categorize items that can be simultaneously classified as both breakfast and bakery items before the categorical task began. One participant did not follow the instructions and expectancy ratings for one participant were not recorded due to a technical problem. Altogether, a total of 10 participants were excluded, leaving 29 participants in the HA group and 31 participants in the LA group (40 females, $M_{age} = 19.8$, $SD_{age} = 3.5$).

Anxiety groups and shock intensities. The mean DASS Anxiety scores were 16.6 and 2.8 for the HA and LA groups, respectively. The HA group had a mean shock intensity of 2.2 mA while the LA group had a mean shock intensity of 2.1 mA. No group difference was found in the tolerance of electric shock, $F(1, 58) = 0.4$, $p = .53$, *ns*.

Acquisition. Figure 2A shows the mean shock expectancy ratings during acquisition for the HA and LA groups. Averaged across the two acquisition blocks, ratings to the CS+ exemplars were higher than the ratings to CS− exemplars, resulting in a significant main effect for CS trial type, $F(1, 58) = 1562.9$, $p < .01$, $\eta_p^2 = 0.96$, 95% CI [3.8, 4.2]. Average ratings to all CSs in the first block were significantly lower than those in the second block, $F(1, 58) = 20.5$, $p < .01$, $\eta_p^2 = 0.26$, 95% CI [−0.5, −0.2], presumably because the net increase in ratings to CS+ was slightly greater than the decrease in ratings to CS− across the two blocks. Acquisition of discrimination was confirmed by a significant interaction between CS trial types and blocks, $F(1, 58) = 267.6$, $p < .01$, $\eta_p^2 = 0.82$, 95% CI [−1.4, −1.1], indicating that the difference in ratings to CS+ and CS− became more pronounced in the

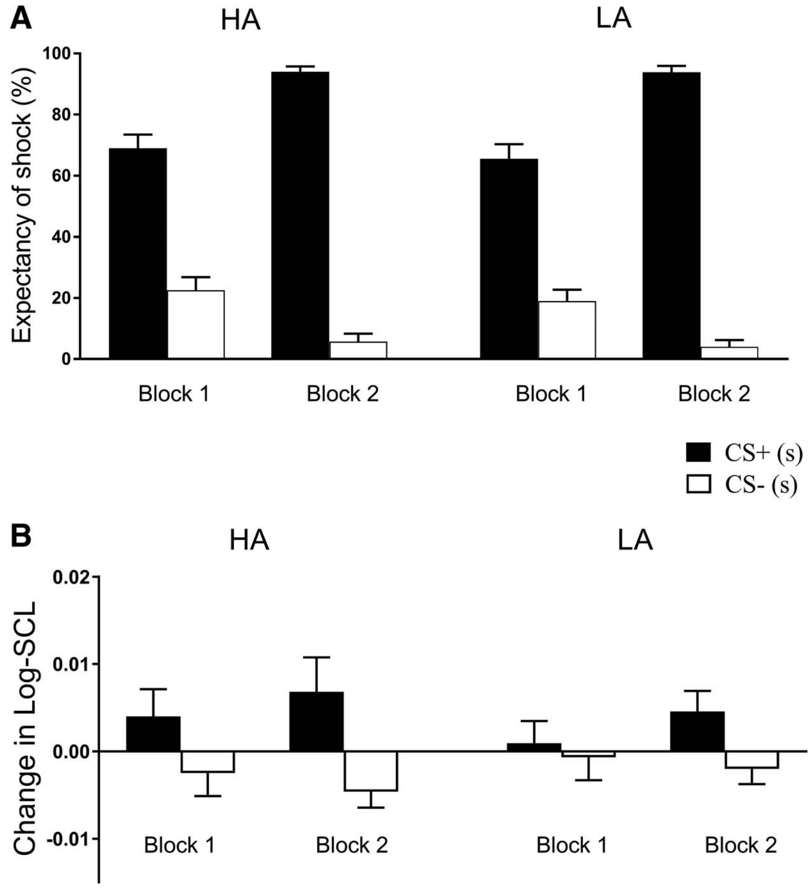

Figure 2. Mean shock expectancy ratings (top panel) and skin conductance level (SCL; bottom panel) across acquisition trials in Experiment 1. HA = high anxious; LA = low anxious; CS+ indicates reinforced exemplars; CS− indicates nonreinforced exemplars.

second block. No interaction effects involving anxiety groups were observed (highest $F = 1.1$, $p = .3$).

Figure 2B shows the mean change in log SCL during acquisition in the HA and LA groups. Averaged across all trials, responding to all CS+s were significantly higher than all CS−s, as shown by a significant main effect for CS trial type, $F(1, 58) = 40.0$, $p < .01$, $\eta_p^2 = 0.4$, 95% CI [0.3, 0.6]. Averaged across CS types, there was no difference in responding to early and late acquisition trials, $F(1, 58) = 0.56$, $p = .46$, *ns.* Similar to the expectancy ratings, differential skin conductance developed across acquisition trials, resulting in a significant interaction between CS trial types and block, $F(1, 58) = 5.8$, $p = .02$, $\eta_p^2 = 0.06$, 95% CI [−0.3, −0.03]. However, unlike expectancy, a significant interaction between CS trial types and groups was also observed, $F(1, 58) = 5.6$, $p = .02$, $\eta_p^2 = 0.06$, 95% CI [0.05, 0.6]. This result is due to HA participants showing a higher level of differential responding to CS+s and CS−s. No other interactions were significant (highest $F = 0.16$, $p = .69$).

Test. Figure 3A shows the shock expectancy ratings to test stimuli in the HA and LA groups in Test 1.[1] Both groups showed significantly higher expectancy ratings to threat category cues (i.e., CS+ and GEN+s) than to safe category cues (i.e., CS− and GEN−s), $F(1, 58) = 3287.5$, $p < .01$, $\eta_p^2 = 0.98$, 95% CI [3.4, 3.6]. Overall ratings to the CSs were similar to those to the GENs, resulting in a nonsignificant difference between CSs and GENs, $F(1, 58) = 0.0002$, $p = .99$, *ns.* However, the difference between ratings to CS+ and GEN+ was slightly smaller than the difference between ratings to CS− and GEN−, confirmed by a significant interaction, $F(1, 58) = 18.1$, $p < .01$, $\eta_p^2 = 0.24$, 95% CI [0.06, 0.2], suggesting greater fear generalization from CS+ to GEN+ than safety generalization from CS− to GEN−. No interactions with group were found (highest $F = 0.2$, $p = .66$), suggesting that trait anxiety had no effect on threat appraisal to unambiguous threat and safety cues regardless of their novelty. The averaged shock expectancy ratings to CC exemplars across groups were significantly higher than that to UC items, $F(1, 58) = 11.0$, $p < .01$, $\eta_p^2 = 0.16$, 95% CI [0.3, 1.3], suggesting an overall higher level of fear responding to CC exemplars when compared to novel food exemplars that did not belong to either the threat or the safe category. This pattern was mostly driven by the HA group, since HA participants showed higher expectancy ratings to the CC exemplars than UC exemplars compared to the LA participants;

[1] Nonaggregated data (i.e., responding to each individual exemplar) are reported in the online supplementary materials.

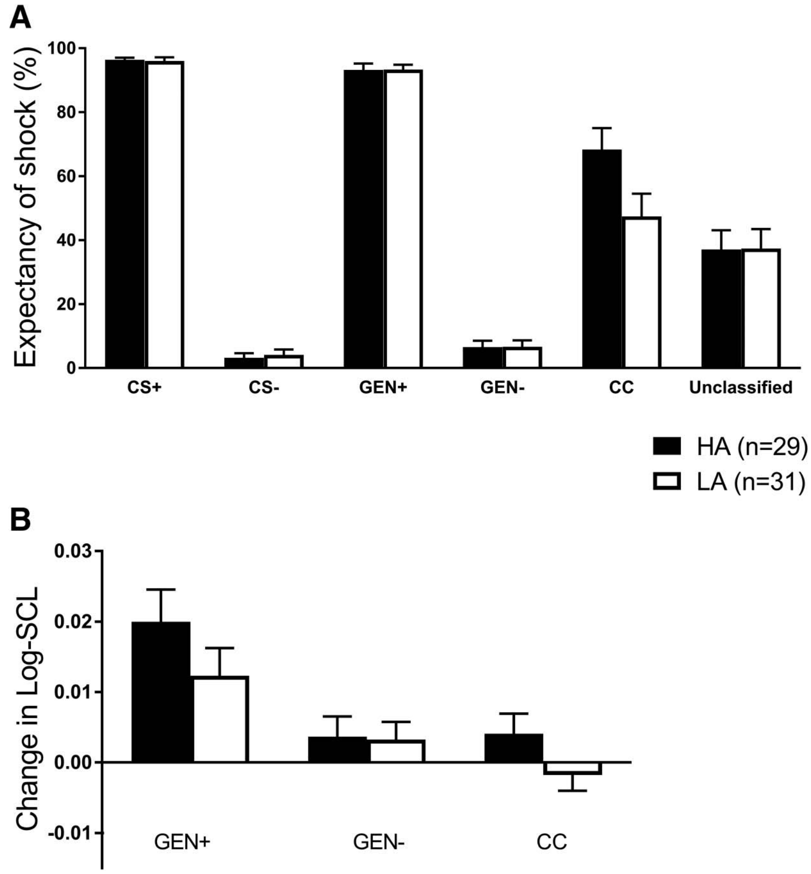

Figure 3. Mean shock expectancy ratings (top panel) and skin conductance level (SCL; bottom panel) across test trials in Experiment 1. HA = high anxious; LA = low anxious; CS+ indicates reinforced exemplars; CS− indicates nonreinforced exemplars; GEN+ indicates exemplars that were in the same category as CS+; GEN− indicates exemplars that were in the same category as CS−; CC indicates cross-classified exemplars. The skin conductance data were collected during Test 2, when the shock electrodes were connected.

however, this interaction did not quite reach significance, $F(1, 58) = 2.9$, $p = .09$, *ns*.

Figure 3B shows the skin conductance data collected in Test 2, which were broadly consistent with the expectancy measures. Averaged across groups, participants showed significantly higher responding to GEN+ than to GEN−, $F(1, 58) = 16.0$, $p < .01$, $\eta_p^2 = 0.23$, 95% CI [0.4, 1.1]. Furthermore, the averaged responding to GEN exemplars was significantly higher than to CC exemplars, $F(1, 58) = 15.4$, $p < .01$, $\eta_p^2 = 0.19$, 95% CI [0.3, 0.8]. HA participants appeared to respond more to GEN+ and CC exemplars than the LA participants, but no interaction effects involving anxiety groups were observed (highest $F = 1.3$, $p = .26$).

Comparison between high and low trait anxiety groups. The initial analysis indicated no significant group differences in responding to the CSs and GENs. Although a group trend was observed in the shock expectancy ratings to CC relative to UC exemplars, this group difference did not quite reach significance. Nonetheless, since we hypothesized a trait anxiety difference in responding to the ambiguous CC exemplars, we carried out a direct comparison of expectancy ratings to the CC exemplars between groups. The HA group had higher overall expectancy ratings to the CC exemplars than the LA group, $F(1, 58) = 9.5$, $p < .01$, $\eta_p^2 = 0.14$, 95% CI [0.3, 1.4]. Similarly, the HA group showed significantly higher skin conductance responding to the CC exemplars than the LA group, $F(1, 58) = 4.7$, $p = .03$, $\eta_p^2 = 0.08$, 95% CI [0.03, 0.7].

Discussion

The current experiment aimed to investigate the effect of trait anxiety on generalization of fear to categorically related objects, in particular to ambiguous cues that can be seen to fit both the threat and safe categories simultaneously.

The results provided strong evidence that fear can be generalized categorically, since fear responding selectively transferred to novel exemplars that belong to the same category as CS+, while inhibitory responding generalized to novel exemplars that belong to the CS− category, in both the shock expectancy and skin conductance measures. Across anxiety groups, expectancy ratings to the ambiguous CC exemplars were higher than to unclassified exemplars. Given that the unclassified items were also food exemplars but were neither breakfast nor bakery items, they controlled for baseline responding to novel, presumably threat-neutral exemplars. This suggests that the increased shock expectancy to

CC exemplars could be attributed to their partial threat value rather than novelty responses.

In terms of a trait anxiety effect, there were no group differences in responding to threat cues (i.e., CS+ and GEN+) or safety cues (i.e., CS− and GEN−), for either the shock expectancy or skin conductance measures. This was presumably because of the clear threat value these exemplars possessed. By contrast, the high anxious group showed higher shock expectancy ratings and skin conductance responses to the ambiguous CC exemplars compared to the low anxious group. Since the CC exemplars could be fitted in both threat and safe categories, there was a conflict in threat value which could be seen as increasing their level of threat ambiguity and hence their level of perceived threat. The present findings are therefore consistent with our initial hypothesis that trait anxious individuals show a bias in threat appraisal to ambiguity, in line with findings in the fear conditioning literature (e.g., Boddez et al., 2012; Chan & Lovibond, 1996; Chen & Lovibond, 2016; Wong & Lovibond, 2018).

Experiment 2

In Experiment 1, HA participants showed higher shock expectancy to the CC exemplars, indicating a bias toward higher threat appraisal under conditions of threat ambiguity. One possible explanation for this pattern is that HA participants recognized that the CC exemplars belonged to both the CS+ and CS− categories, but then focused on the worst of these two possibilities when rating their shock expectancy. However, another possibility is that the effect occurred at the level of categorization; perhaps the HA participants were more likely to see the CC exemplars as belonging to the CS+ category and for this reason showed a higher expectancy of shock. Therefore, in Experiment 2 we added a forced-choice categorization task for the CC exemplars between acquisition and test, to test between these possibilities. If the locus of the expectancy bias in HA participants is at the level of categorization then we would expect them to classify more CC exemplars as belonging to the CS+ category as well as showing the bias in shock expectancy observed in Experiment 1. Conversely, if HA participants recognize that the CC exemplars could belong to either category but fear the worst, then we would expect them to show no bias in the classification test but nonetheless show the bias in shock expectancy.

Method

Participants. Sixty undergraduates were recruited as participants who received course credit or AUD $15 for participation. Participants with a DASS anxiety score of 14 or above were assigned into the HA group, while those with a DASS anxiety score of 4 or below were recruited to the LA group. The prescreening criterion for HA group was slightly lower compared to Experiment 1 due to difficulty in recruitment. As in Experiment 1, we expected a medium-large effect of trait anxiety on responding to ambiguous cues. The minimum sample size to achieve a power of 80% to detect this effect was 54. We recruited a total of 60 participants, with 30 participants in each group.

Apparatus and materials. All the apparatus and materials were the same as those used in Experiment 1.

Procedure. The procedure was exactly the same as that followed in Experiment 1, except in the following aspects: Immediately after acquisition, participants were asked to complete a forced-choice categorization task. Participants were verbally informed that no shock would be administered in this phase, and that pictures would be presented, with the word *breakfast* located left of the picture and *bakery* located right of the picture. Participants were asked to categorize the picture shown into either breakfast or bakery as fast as possible. If participants perceived the item as a breakfast item, they had to press the left arrow key; if they perceived the item as a bakery item, they had to press the right arrow key. Three CC exemplars that were identical to the ones to be presented in the subsequent generalization test were shown once each. After the categorization test, Test 1 and Test 2 were presented exactly as in Experiment 1.

Scoring and analysis. For the newly added forced-choice categorization task, the number of participants perceiving CC exemplars as belonging to either the threat or safe category were analyzed across groups. Furthermore, expectancy ratings and skin conductance responses to each CC exemplar were evaluated to see whether the categorization of CC exemplars affected responding to them correspondingly. Additionally, group differences were also evaluated to see if there was any interaction between trait anxiety and categorization on responding to CC exemplars. The remaining analyses were the same as in Experiment 1.

Results and Discussion

Exclusion of participants. Four participants in the HA group and one participant in the LA group were excluded based on the acquisition criterion. One participant in the LA group was excluded for not making more than two expectancy ratings in Test 1. Altogether, four HA and two LA individuals were excluded, resulting in 26 participants in the HA group and 28 participants in the LA group (39 females, $M_{age} = 19.6$, $SD_{age} = 2.3$).

Anxiety groups and shock intensities. The mean DASS anxiety scores were 14.7 and 1.36 for the HA and LA group, respectively. The mean shock intensities were 2.5 mA and 2.7 mA for the HA and LA group, respectively. There was no significant group difference in the tolerance of electric shock, $F(1, 52) = 0.8$, $p = .39$, *ns.*

Acquisition. Figure 4A shows the mean shock expectancy ratings during acquisition for the HA and LA group. The pattern was similar to Experiment 1. Across both anxiety groups and blocks, participants showed significantly higher shock expectancies to the CS+ than to the CS−, confirmed by a significant main effect for CS trial type, $F(1, 52) = 729.5$, $p < .01$, $\eta_p^2 = 0.93$, 95% CI [3.3, 3.8]. Averaged expectancy ratings across CSs in the first block were significantly lower than those in the second block, $F(1, 52) = 14.9$, $p < .01$, $\eta_p^2 = 0.22$, 95% CI [−0.4, −0.1], presumably because the net increase in ratings to CS+ was slightly greater than the decrease in ratings to CS− across the two blocks. Importantly, the interaction between CS type and block was significant, $F(1, 52) = 270.2$, $p < .01$, $\eta_p^2 = 0.84$, 95% CI [−1.4, −1.1], confirming the development of differential responding to CS+ and CS− across blocks. No interactions involving anxiety groups were observed (highest $F = 2.2$, $p = .14$), suggesting that there were no differences in acquisition between anxiety groups.

Figure 4B shows the mean change in log SCL during acquisition in the HA and LA groups. Averaged across groups and blocks, participants showed more responding to CS+ than to CS−, con-

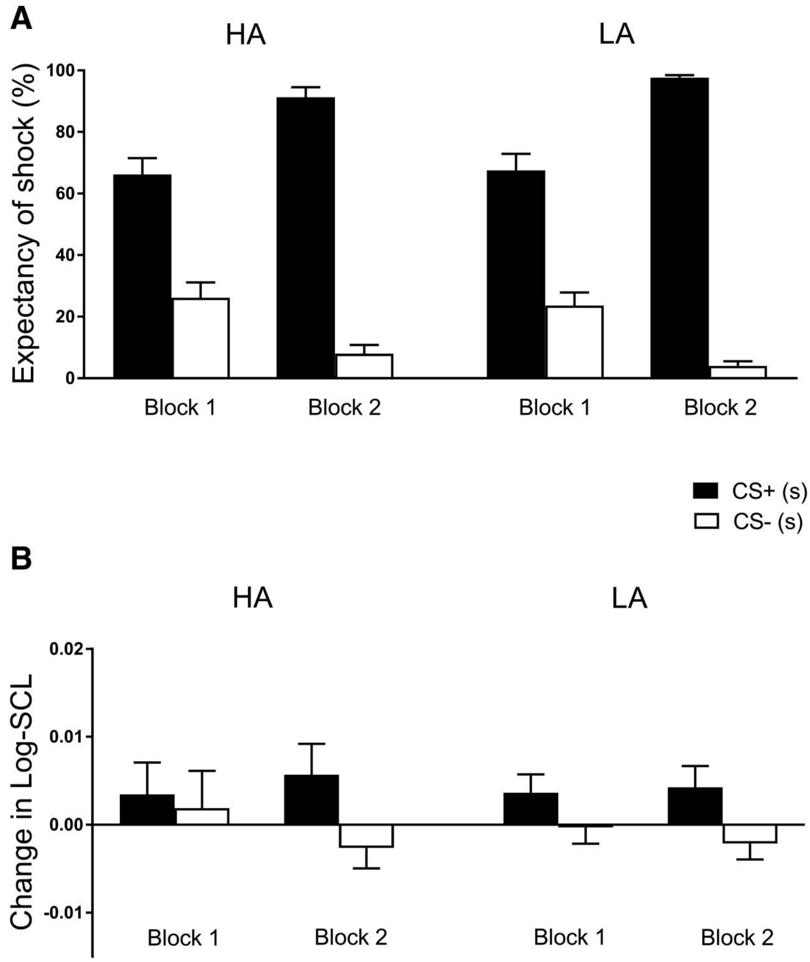

Figure 4. Mean shock expectancy ratings (top panel) and skin conductance level (SCL; bottom panel) across acquisition trials in Experiment 2. HA = high anxious; LA = low anxious; CS+ indicates reinforced exemplars; CS− indicates nonreinforced exemplars.

firmed by a main effect for CS trial type, $F(1, 52) = 17.3$, $p < .01$, $\eta_p^2 = 0.24$, 95% CI [0.2, 0.5]. Although no differences in responding to the CSs were observed between blocks, $F(1, 52) = 0.67$, $p = .42$, *ns*, responding to CS+ and CS− differentiated across blocks, as shown by a significant interaction between CS trial type and block, $F(1, 52) = 7.7$, $p < .01$, $\eta_p^2 = 0.11$, 95% CI [−0.3, −0.04]. Similar to the expectancy data, no interaction effects between anxiety groups were found (highest $F = 1.7$, $p = .20$), suggesting no group differences in fear acquisition.

Test. Figure 5A shows the expectancy ratings to test stimuli in the HA and LA groups. Both groups showed higher threat appraisal to threat cues (i.e., CS+ and GEN+s) than to safety cues (i.e., CS− and GEN−s), confirmed by a significant difference in shock expectancies to threat and safety cues, $F(1, 52) = 407.8$, $p < .01$, $\eta_p^2 = 0.89$, 95% CI [2.4, 3.0]. Overall, expectancy ratings to the CSs did not differ from those to the GEN exemplars, $F(1, 52) = 0.03$, $p = .86$, *ns.* The interaction between threat type and trial type was significant, $F(1, 52) = 14.3$, $p < .01$, $\eta_p^2 = 0.22$, 95% CI [0.09, 0.3], suggesting smaller generalization decrement from CS+ to GEN + than from CS− to GEN−. Surprisingly, HA individuals showed lower expectancy ratings to threat cues (i.e., CS+ and GEN+) relative to LA individuals, while an opposite pattern was observed in responding to safety cues (i.e., poorer discriminative learning; CS− and GEN−) in the HA group. This pattern was confirmed by a significant group difference in the responding between threat cues and safety cues, $F(1, 52) = 4.8$, $p = .03$, $\eta_p^2 = 0.09$, 95% CI [−1.1, −0.05]. Both groups had significantly higher expectancy ratings to the CC exemplars than to the UC exemplars, $F(1, 52) = 5.9$, $p = .02$, $\eta_p^2 = 0.10$, 95% CI [0.09, 0.9]. This contrast also interacted with group, $F(1, 52) = 7.2$, $p = .01$, $\eta_p^2 = 0.12$, 95% CI [0.3, 2.0], suggesting that the difference in ratings to CC and UC exemplars was not the same across groups. In fact, the HA group showed higher expectancy ratings to the CC exemplars than to the UC exemplars, while ratings to both the CC and UC exemplars were highly similar in the LA group. No other interactions were observed between groups (highest $F = 1.2$, $p = .28$).

Figure 5B shows the skin conductance data collected in Test 2. Averaged across groups, participants showed significantly higher responding to GEN+ than to GEN−, $F(1, 52) = 13.9$, $p < .01$,

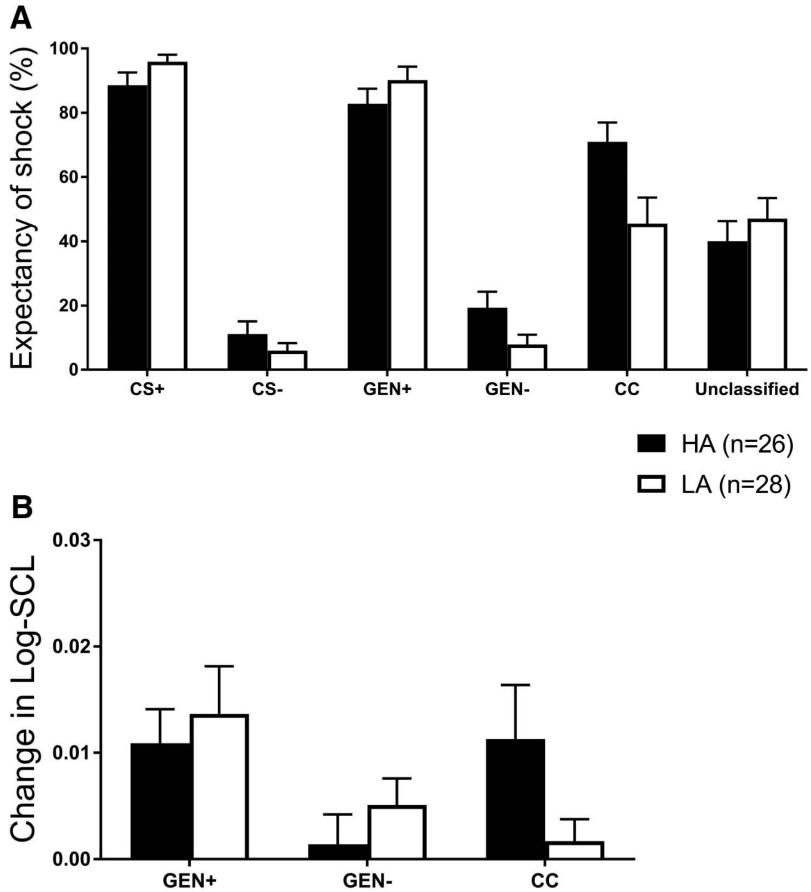

Figure 5. Mean shock expectancy ratings (top panel) and skin conductance level (SCL; bottom panel) across test trials in Experiment 2. HA = high anxious; LA = low anxious; CS+ indicates reinforced exemplars; CS− indicates nonreinforced exemplars; GEN+ indicates exemplars that were in the same category as CS+; GEN− indicates exemplars that were in the same category as CS−; CC indicates cross-classified exemplars. The skin conductance data were collected during Test 2, when the shock electrodes were connected.

$\eta_p^2 = 0.2$, 95% CI [0.2, 0.7]. No differences were observed in the comparison between responding to GEN and CC exemplars across groups, $F(1, 52) = 0.2$, $p = .66$, *ns.* However, the HA group responded more to the CC exemplars than to the averaged GEN exemplars when compared to the LA group, $F(1, 52) = 6.2$, $p = .02$, $\eta_p^2 = 0.1$, 95% CI [−1.2, −0.1]. No other interactions between anxiety groups were observed (highest $F = 0.03$, $p = .86$).

Categorical test. An omnibus Cochrans-Q test was carried out to examine any differences in the categorization of CC exemplars. Surprisingly, more LA participants categorized the CC exemplars as belonging to the threat category averaged across all three exemplars, $\chi^2[2] = 10.6$, $p < .01$.

Nonetheless, follow-up analyses were carried out to examine how the categorization of CC exemplars and trait anxiety may affect responding to these exemplars in both expectancy and skin conductance measures. An overall analysis was not possible since the same participant could have rated one CC exemplar (e.g., croissant) as threatening while rating another CC exemplar (e.g., toast) as safe. Therefore, we only analyzed participants who either rated all CC exemplars into either the threat or the safe category.[2] This analysis provides two advantages. First, it allows an overall analysis to be carried out. Second, trait anxiety effects may be more pronounced.

Five HA and 11 LA participants categorized all CC exemplars into the threat category, while five HA and two LA participants categorized all CC exemplars into the safe category. Figure 6A shows the overall expectancy ratings to the CC exemplars according to how participants categorized them. HA participants had higher expectancy ratings to CC exemplars regardless of how they categorized them, supported by a significant main effect for anxiety, $F(1, 19) = 9.0$, $p < .01$, $\eta_p^2 = 0.32$, 95% CI [0.3, 1.8]. Averaged across groups, participants also showed higher expectancy ratings to CC exemplars when they classified them into the threat category, supported by a significant main effect for categorization, $F(1, 19) = 5.3$, $p = .03$, $\eta_p^2 = 0.22$, 95% CI [0.07, 1.6]. However, these effects did not interact, $F(1, 19) = 0.4$, $p = .54$, *ns.*

[2] We have also included analyses for individual CC exemplars where all participants were included. Similar results were found. These analyses are included in the online supplementary materials.

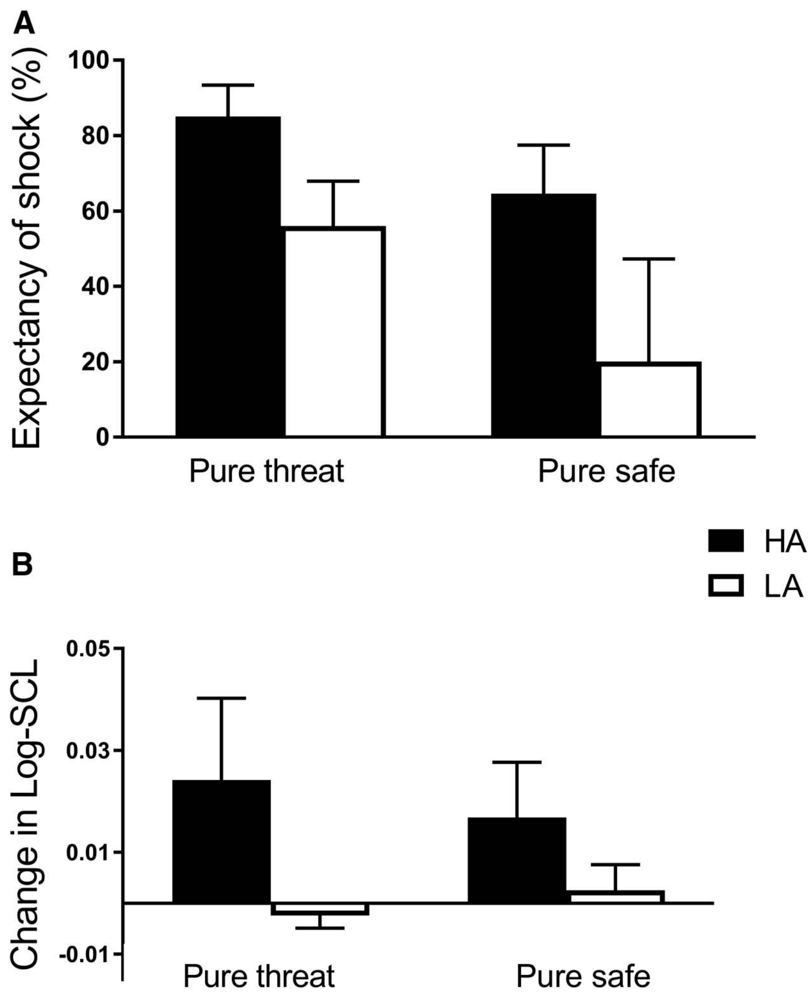

Figure 6. Mean shock expectancy ratings (top panel) and skin conductance level (SCL; bottom panel) to the cross-classified exemplars according to how participants categorized them. HA = high anxious; LA = low anxious.

Figure 6B shows the skin conductance data. Similar to the expectancy measure, HA participants showed more fear responding to all CC exemplars regardless of how they categorized them, confirmed by a significant main effect for anxiety, $F(1, 19) = 6.3$, $p = .02$, $\eta_p^2 = 0.23$, 95% CI [0.2, 1.7]. However, no other effects reached significance (highest $F = 0.6$, $p = .45$).

General Discussion

Across two experiments using a differential fear conditioning paradigm, we found that fear selectively generalized to novel exemplars that belong to the CS+ category, but not to those belonging to the CS− category. In other words, the categorical membership of exemplars allowed participants to evaluate their threat value accordingly. This pattern is consistent with past studies, which found that conditioned fear generalizes to novel cues that are perceptually dissimilar but categorically related to the trained threat cues (e.g., Dunsmoor & colleagues, 2012; Dunsmoor & Murphy, 2014; Meulders et al., 2017). Two aspects of the current study provided strong evidence for higher-order fear generalization. First, differential responding to CS+ and CS− exemplars was established rapidly within the first acquisition block. Given that each exemplar was presented only once per block, this pattern suggests that participants had learnt that the shock predictiveness was based on the categorical membership of exemplars. If participants were instead learning the CS−shock association for every exemplar, responding should have been irregular in the first acquisition block. This finding is consistent with Dunsmoor and colleagues' studies (Dunsmoor et al., 2012; Dunsmoor & Murphy, 2014), which also found differential responding early in acquisition, favoring the interpretation that participants learnt categorically. Second, little generalization decrement was observed from CS+ to GEN+ exemplars, and similarly from CS− to GEN− exemplars. This is presumably due to participants perceiving the novel GEN exemplars as another CS exemplar, because of the shared categorical membership.

With regard to trait anxiety, both groups showed a similar degree of generalization to the novel GEN+ and GEN− exemplars in both the expectancy and skin conductance measures. Since both GEN+ and GEN− exemplars clearly belonged to either the threat or the safe category, they had unambiguous threat value despite their novelty. This finding aligned with our prediction that trait anxious individuals would not show increased threat appraisal to generalization exemplars when their level of threat ambiguity remained relatively low.

The critical finding was that trait anxious individuals showed higher fear responding to the ambiguous CC exemplars compared to the low anxious group. Since the CC exemplars could be seen as fitting in both the threat and safe categories, there was a conflict in threat value and hence their predictiveness of shock became ambiguous. This finding is consistent with past fear conditioning studies that found a bias in fear responding to ambiguity among high anxious individuals (e.g., Boddez et al., 2012; Chan & Lovibond, 1996; Chen & Lovibond, 2016). Using a conditioned inhibition paradigm, Chan and Lovibond (1996) found that trait anxious individuals showed higher expectancy ratings to both threat and safety cues than low anxious individuals, but this effect was only observed among those unaware of the CS−shock contingency. Since the unaware participants did not know which cue predicted shock, all cues in the task effectively became ambiguous. Chen and Lovibond (2016) found a similar effect of threat ambiguity in individuals with high intolerance of uncertainty, a vulnerability factor for developing anxiety disorders (e.g., Boelen & Reijntjes, 2009; Dugas, Gagnon, Ladouceur, & Freeston, 1998; Fetzner, Horswill, Boelen, & Carleton, 2013). The current findings also conceptually align with the idea that trait anxious individuals show overgeneralization, but only under conditions of threat ambiguity (Wong & Lovibond, 2018).

Across both experiments, no group differences were observed in responding to the safety cues (i.e., CS−). Although trait anxious individuals showed poorer discriminative ratings to the threat and safety cues in Experiment 2, this pattern was not solely driven by an increase in ratings to the safety cues. Instead, it was driven by both a decrease in ratings to the threat cues and an increase in ratings to the safety cues among trait anxious individuals. This suggests that trait anxious individuals did not display a specific impairment in safety learning. This finding is inconsistent with past findings in the literature (e.g., Gazendam et al., 2013; Grillon & Ameli, 2001; Haaker et al., 2015). However, there have been other studies that suggested impaired safety learning among trait anxious individuals is modulated by threat ambiguity. Chan and Lovibond (1996) found that trait anxious individuals showed elevated fear responses to both threat and safety cues, but only when they were unaware of the CS−shock contingency. Similarly, Baas, van Ooijen, Goudriaan, and Kenemans (2008) found a similar effect of trait anxiety using a conditional discrimination paradigm. Participants were presented with the CSs in one of the two contexts. While CS− was never reinforced regardless of the context it was presented in, CS+ was only followed by a shock when presented in one context (i.e., shock context) but not the other (i.e., safe context). Participants were assessed on whether they were aware that the shock contingency of CS+ was context dependent, and were categorized into the aware and unaware group accordingly. The authors found that participants in the unaware group scored higher in trait anxiety than the aware group, and also showed increased responding to CS− when presented in the shock context in both self-reported and skin conductance measures.

Collectively, these studies suggest that impaired safety learning in trait anxious individuals may be restricted to those who are unaware of the relevant contingencies, since not knowing which cue predicts shock effectively creates threat ambiguity. Some past studies that found impaired safety learning in anxious individuals did not assess participants' awareness of the CS–shock or Context–shock contingency (e.g., Grillon & Ameli, 2001; Haaker et al., 2015), so it is possible that the increase in conditioned fear to safety cues or safety context was largely driven by trait anxious individuals who were not aware of the relevant contingencies. Given that all participants across both of the current experiments were aware of the correct CS category–shock association as assessed by the postexperimental questionnaire, threat ambiguity presumably derived from a different source, namely ambiguous category membership.

The second experiment showed that trait anxious individuals were not more likely to categorize the ambiguous CC exemplars into the threat category. In other words, trait anxious individuals did not show a bias toward categorizing cross-classified stimuli as threatening, as predicted by some models of cognitive bias (Eysenck et al., 1987; MacLeod & Cohen, 1993). Instead, trait anxious individuals showed a general increase in fear responding to the ambiguous CC exemplars regardless of how they categorized them. This main effect of trait anxiety seen in both experiments suggests that trait anxious individuals exhibit a bias toward overestimation of threat under ambiguous conditions—sometimes referred to as a "better safe than sorry" strategy (Eysenck et al., 1987; Lommen, Engelhard, & van den Hout, 2010). Indeed, some participants reported that although they perceived the CC exemplars as safe, they made higher expectancy ratings to mentally prepare themselves for shock in case the CC exemplars would be followed by a shock in Test 2. There is also some evidence that trait anxious individuals are less confident about their judgments under stress (Fathi-Ashtiani, Ejei, Khodapanahi, & Tarkhorani, 2007; Goette, Bendahan, Thoresen, Hollis, & Sandi, 2015). Therefore, trait anxious individuals may not have been fully confident about their judgment that CC exemplars had an intermediate level of threat, and instead defaulted to an estimate at the upper end of the range.

One may argue that the unclassified exemplars also had ambiguous threat value, since their threat value was unknown (cf. Chen & Lovibond, 2016). Therefore, trait anxious individuals should have also shown more conditioned fear to them compared to the low anxious group. This pattern was not observed in the current study, possibly due to the CS− exemplars belonging to the same superordinate category as the novel exemplars (food). This may have led to the conclusion that "not all foods lead to shock," reducing the threat ambiguity induced by unclassified exemplars. This reduction of threat ambiguity may have then attenuated any trait anxiety effect on fear generalization to the unclassified exemplars. This explanation predicts that if the CS− exemplars belonged to a completely different category (e.g., tools), the threat ambiguity of the unclassified exemplars would have increased since the conclusion that "all food cause shock" is not violated. In fact, our lab has recently shown such an effect of dissimilar CS−s on the breadth of generalization (Lee, Lovibond, Hayes, & Navarro, 2019).

The finding of overgeneralization of fear to ambiguous CC exemplars in trait anxious participants suggests that overgeneralization of fear is a predispositional factor for the development of anxiety disorder (Lenaert et al., 2014; Wong & Lovibond, 2018). In fact, overgeneralization of fear under conditions of threat ambiguity may serve as a predictive behavioral marker for the development of anxiety disorders or severity of anxiety symptoms after trauma exposure. For instance, future studies could test populations at high risk of trauma exposure (e.g., firefighters, paramedics), and examine if overgeneralization of fear prior to trauma exposure is a good predictor of the development of anxiety disorders (cf. Guthrie & Bryant, 2006; Pole et al., 2009).

The finding that trait anxious individuals only showed overgeneralization of fear to ambiguous novel exemplars is consistent with the notion that ambiguous threat leads to elevated threat appraisal in trait anxiety (e.g., Boddez et al., 2012; Chan & Lovibond, 1996; Chen & Lovibond, 2016). This suggests that anxious patients will benefit from therapeutic strategies that help them to disambiguate a potentially threatening situation. Chen and Lovibond (2016) suggested that explicitly training patients to quantify threat probability under conditions of threat ambiguity may help them to more adaptively evaluate the probability of novel threat in the future.

In conclusion, the present work replicated the finding of higher-order categorical fear generalization in humans (Bennett et al., 2015; Dunsmoor et al., 2012; Dunsmoor & Murphy, 2014; Meulders et al., 2017). More importantly, we found that trait anxious individuals showed overgeneralization of fear, but only to stimuli that had ambiguous threat value. This suggests that fear generalization is largely an adaptive process even in trait anxious individuals; however, it may become maladaptive under conditions of threat ambiguity. This effect was not due to trait anxious individuals interpreting ambiguity in a threatening way, but instead to an overestimation of threat under ambiguity. Furthermore, trait anxious individuals did not show impaired safety learning, presumably because the safety cues had clear (low) threat value. This pattern further supports the notion that fear learning among trait anxious individuals is modulated by threat ambiguity. The current work also suggests that overgeneralization of fear under conditions of threat ambiguity may be a behavioral marker for the development of anxiety disorders.

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