Suffering More in Imagination Than in Reality: Mental Imagery and Fear Generalization

by

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Abstract

Mental imagery may represent a weaker form of perception and, thus, mental images may be more ambiguous than visual percepts. If correct, the acquisition of fear would be less specific for imagined fears in comparison to perceptual fears, perhaps facilitating broader fear generalization. To test this idea, a two-day differential fear conditioning experiment (*N* = 98) was conducted. On day one, two groups of participants underwent differential fear conditioning such that a specific Gabor patch orientation (CS+) was paired with mild shocks (US) while a second Gabor patch of orthogonal orientation (CS-) was never paired with shock. Critically, one group imagined the Gabor patches and the other group was visually presented the Gabor patches. Next, both groups were presented visual Gabor patches of similar orientations (GCS) to the CS+. On day two, to assess the persistence of imagined fear, participants returned to the lab and were tested on the GCS devoid of shock. For day one, in contrast to our primary hypothesis, both self-report and skin conductance response measures did not show a significant interaction between the GCS and groups. On day two, both measures demonstrated a persistence of imagined fear, without US delivery. Taken together, rather than demonstrating an overgeneralization effect, the results from this study suggest that imagery-based fear conditioning generalizes to a similar extent as perceptually acquired fear conditioning. Further, the persistence of imagery-based fear may have unique extinction qualities in comparison to perceptual-based fear.

Keywords: mental imagery, fear, fear conditioning, generalization, anxiety

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List of Abbreviations

CS+	Conditioned stimulus paired with shock
CS-	Conditioned stimulus unpaired with shock
GCS+10	Generalized conditioned stimulus that is positive ten degrees from the conditioned stimulus paired with shock
GCS+20	Generalized conditioned stimulus that is positive twenty degrees from the conditioned stimulus paired with shock
GCS+30	Generalized conditioned stimulus that is positive thirty degrees from the conditioned stimulus paired with shock
GCS-10	Generalized conditioned stimulus that is negative ten degrees from the conditioned stimulus paired with shock
GCS-20	Generalized conditioned stimulus that is negative twenty degrees from the conditioned stimulus paired with shock
GCS-30	Generalized conditioned stimulus that is negative thirty degrees from the conditioned stimulus paired with shock

Introduction

Up to 33.7% of the population are affected by anxiety disorders (Bandelow & Michaelis, 2015), and several lines of research indicate uncontrolled fear generalization as a crucial factor in these psychopathologies (Aikins & Craske, 2001; Kaczkurkin et al., 2017; Lissek et al., 2005). Although there is an abundance of research on how fear associations generalize (Dunsmoor & Paz, 2015; Lissek, Kaczkurkin, et al., 2014), these studies have focused on perceptual or *in vivo* fear associations rather than those of imagined fear associations. Importantly, anxiety disorders are mostly an internal experience characterized by an individual's rumination that centers on fearful stimuli (Aikins & Craske, 2001; Homer & Deeprose, 2017). Therefore, examining how fear can spread in one's imagination may provide novel evidence toward the understanding of fear as well as to the etiology of certain psychopathologies. Ultimately, the aim of the present study is to uncover whether fear associations formed through mental imagery, compared to perception, are prone to broader fear generalization.

Mental Imagery

Several theories exist regarding the mechanisms that support mental imagery, the perception-like experience devoid of necessary external stimuli (Lewis et al., 2013), as well as mental imagery's connection to emotion. Recent research argues that mental imagery may represent a similar, yet attenuated form of perception (Pearson et al., 2011, 2015); such that mental images are depictive and one "sees" in their "mind's eye" (Kosslyn et al., 2001). In this way, a mental image could stand in for a visual percept (Lewis et al., 2013). Alternatively, the bio-informational theory of mental imagery asserts that imagination is conceptual as well as depictive. Importantly, this theory posits that it is the propositional nature of mental imagery that elicits one's emotional reactions (Lang, 1977, 1979). Regarding emotion research, the crucial commonality between these theories is that mental images appear to have the capability of eliciting emotional reactions comparable to visual percepts.

Fear Conditioning and Mental Imagery

Recent emotion research has begun to accumulate regarding the interaction between mental imagery and fear (Mertens et al., 2020). In attempts to better comprehend fear, researchers employ differential fear conditioning paradigms. For example, differential conditioning can be achieved by pairing one neutral stimulus (CS+) with an aversive stimulus (US; e.g., mild shock), and never pairing a similar neutral stimulus (CS-) to that shock. This shock will cause an individual to display an unconditioned fear response (UR). After pairing the CS+ and US, presentation of the CS+ will elicit a similar response (CR) as the UR (e.g., increased self-report of fear, skin conductance response (SCR), heart rate, pupil dilation). Researchers quantify the difference in one's CR to the CS+ and CS-, which serves as evidence to whether the individual developed a fear specifically toward one stimulus.

One of the most widely used methods to index an individual's CR is by measuring their electrodermal activity via SCR. During fear conditioning, CS+ onset typically generates larger autonomic nervous system reactions in comparison to the CS-. This differential in autonomic nervous system reactivity can be estimated by collecting an individual's SCR at CS+ and CS- onset. Importantly, by extension, these individuals' fear toward the CS+ and CS- can be implied from these SCR recordings, as an increase in autonomic nervous system reactivity is associated with the experience of fear (Lonsdorf et al., 2017). However, fear is not simply a physiological phenomenon. Instead, fear has been argued to be physiological as well as subjective (Mobbs et al., 2019). Indeed, research suggests that one's conscious knowledge of a fearful stimulus can critically impact their behavioural and emotional reactions (LeDoux, 2014; LeDoux & Hofmann, 2018). In this way, one's self-reported fear of the CS+ and CS- can also index an individual's level of fear; although the necessity of consciousness and fear remains controversial (Berridge, 2018). Nevertheless, advances in fear conditioning research recommend corroborating multiple measures (e.g., subjective, physiological) to assess one's fear most accurately during conditioning (Jiang et al., 2021; Lonsdorf et al., 2017).

Historically, fear conditioning has only measured fear using *in vivo* stimuli, which may not account for the internal experience of fear (Lewis et al., 2013). Intriguingly, contemporary research has adapted this long-standing paradigm to incorporate one's imagination. One example of this ingenuity is the use of imagined conditioned stimuli (CSs). Utilizing this idea, Burleigh et al. (2022) observed that one can pair a physical US with an imagined CS+ to produce a CR that transfers to instances of viewing the corresponding CS+. Similarly, recent research has demonstrated that pairing a US to a visual CS+ produced a CR that was transferred to an imagined CS (Greening et al., 2022). Moreover, studies have suggested that repeated mental imagery of a fearful stimulus is sufficient in extinguishing CRs to a similar level as repeated perceptual exposure (Grégoire & Greening, 2019; Jiang & Greening, 2021).

When narrowing to the neurological level, brain imagining studies suggest that both imagination and perception of the same stimulus similarly activate early visual systems (Barton & Cherkasova, 2003; Pearson et al., 2015). Corroborating these findings, transcranial magnetic stimulation of these visual areas can impair both mental imagery as well as perception (Kosslyn et al., 1999). Furthermore, researchers employing multivoxel pattern analysis have demonstrated that one can accurately decode a perceptual stimulus while that individual is imagining the corresponding stimulus (Albers et al., 2013; Harrison & Tong, 2009; Naselaris et al., 2015). Collectively, these studies suggest an underlying similarity between mental imagery and perception. Moreover, perhaps due to this similarity, both modalities have been shown to engender analogous fear acquisition and extinction through the use of imagined CSs (Jiang & Greening, 2021). However, a gap in the literature exists regarding how imagined fear generalizes in comparison to perceptual fear.

Fear Generalization

Fear research suggests that one's fear does not necessarily solidify on the CS+. Instead, fear can spread to novel, yet perceptually similar stimuli (generalized conditioned stimuli (GCS)). The broadness of one's fear generalization is measured by how analogous an individual's CR is toward the CS+ versus GCS (Dunsmoor & Paz, 2015; Meulders et al., 2015). For example, when an individual is fear conditioned to a Gabor patch orientation at 45° (CS+), the broadness of this individual's fear generalization can be quantified by measuring their CR when viewing progressively distant Gabor patches from the CS+, such as orientations of 55°, 65°, and 75° (McTeague et al., 2015). Consequently, an individual's CR to these new orientations creates a gradient. Researchers measure these gradients from the highest fear response, the CS+, to the least similar GCS (Huggins et al., 2021). Generally, individuals demonstrate a high response to the CS+, followed by a steep decline in their gradient, ending with a flattening of the curve (Armony et al., 1997). Alternatively, an individual who has similar CRs toward the CS+ and GCS would demonstrate a relatively gentle decline in their gradient, which can serve as evidence that the individual's fear had abnormally generalized (Lissek, Kaczkurkin, et al., 2014).

Unfortunately, the answer to why imprecise fear generalization occurs remains elusive. Researchers believe the mechanism contributing to canonical generalization may have an adaptive significance (Wicken et al., 2021), as generalizing similar events allows for one to learn optimally (Dunsmoor & Paz, 2015; Meulders et al., 2015; Onat & Büchel, 2015). However, an escalation of this adaptive mechanism can lead to overgeneralization (Lissek et al., 2005; Lissek, Kaczkurkin, et al., 2014), which is characterized by the misguided fear one displays toward a safe stimulus that loosely resembles a feared stimulus. One proposed mechanism by which overgeneralization occurs is aberrant hippocampal activity. Employing fear generalization paradigms, several studies have observed inhibited hippocampal activity in individuals with overgeneralizing disorders, such as post-traumatic stress disorder and generalized anxiety disorder (Berg et al., 2021; Hanert et al., 2019; Huggins et al., 2021; Kaczkurkin et al., 2017; Lissek, Kaczkurkin, et al., 2014). Interestingly, another characterizing feature of these overgeneralizing disorders is intrusive mental images (Hirsch & Holmes, 2007). In this way, overgeneralization may be linked to mental imagery, although exploration of how fear interacts with imagination may be lacking in the literature (Lewis et al., 2013).

Another area of exploration exists regarding the persistence of generalization gradients. Typically, during a one-day study, researchers will administer the US intermittently to the CS+ when participants are being tested on the GCS. These booster trials are employed to defend against the acquired fear extinguishing during generalization testing (Lissek, Kaczkurkin, et al., 2014). Interestingly, Honig & Urcuioli (1981) suggested that booster trials can affect the slope of generalization gradients; although, upon examination, there appears to be a dearth of experiments that assess gradients devoid of booster trials. Furthermore, the literature is sparse regarding how one's gradient reacts after a night of consolidation. To fill these gaps in the literature, the inclusion of multiple generalization testing days without boosters could allow for a more robust assessment of the generalization phenomenon.

Taken together, research has demonstrated that mental imagery and emotion can be studied through the use of imagined CSs (Lewis et al., 2013). When employing this tactic, researchers have been able to reliably show a transfer of fear from imagination to perception and vice-versa (Burleigh et al., 2022; Greening et al., 2022; Jiang & Greening, 2021). To date, however, there is a gap in the literature regarding how this transfer generalizes. Extant research exists suggesting that fear creates a steep generalization gradient (Dunsmoor & Paz, 2015; Lissek, Kaczkurkin, et al., 2014; McTeague et al., 2015). Limitingly, these studies have all employed perceptual stimuli, perhaps not accounting for an imaginative contribution toward fear. Therefore, an unexplored avenue remains in examining how generalization following fear conditioning to an imagined CS+ reacts and persists in comparison to perceptual generalization. Intriguingly, one may be able to create and maintain an imagined fear association using the same mechanisms as perception; however, because imagery is a weaker form of perception, the image may be more ambiguous in the “mind’s eye”, which could contribute to overgeneralization. Importantly, this overgeneralized fear would also transfer from one’s imagination to *real life* when encountered.

Clinical Applications

Uncovering the mechanisms of how mental imagery interacts with fear would have far reaching clinical relevance. Recently, Homer and Deeprose (2017) advanced the proposition that negative mental imagery may be causally linked to increased anxiety. Additionally, research suggests that intrusive mental imagery may spark rumination for distressing stimuli, potentially reinforcing an individual’s fear (Homer & Deeprose, 2017). Congruent with these claims, research suggests that intrusive mental images are characteristic in most anxiety disorders, such as post-traumatic stress disorder, social anxiety disorder, agoraphobia, specific phobia, and generalized anxiety disorder (Aikins & Craske, 2001; Day et al., 2004; Hirsch & Holmes, 2007; Pitman et al., 2012; Pratt et al., 2004). Understanding that fear associations created using imagery are more ambiguous and, thus, prone to broader generalization, may illuminate the pernicious nature of these internalizing disorders.

The Current Investigation

The primary aim of the present study was to evaluate the generalization of differential fear conditioning acquired to imagined conditioned stimuli (CSs) paired with a physical US (mild shock), which we refer to as an imagery-based fear, in comparison to the generalization of standard differential fear conditioning acquired to perceptual conditioned stimuli (CSs) paired with the same physical US (mild shock), which we refer to as a perceptual-based fear. To assess this aim, two separate groups of participants completed four phases of a differential fear conditioning paradigm that spanned two days. Specifically, after completing a brief habituation phase, the acquisition phase consisted of the Visual group undergoing differential fear conditioning such that they were fear conditioned to a visual CS+ (e.g., 45° Gabor patch) and a visual CS- (e.g., 135° Gabor patch), whereas the Imagery group was instructed to imagine the CS+ and CS- at the same orientations, similar to the acquisition procedure of Burleigh et al. (2022). Next, during the generalization phase, both groups were tested on how their fear had generalized by viewing Gabor patches at 10, 20, and 30 degrees (GCS) from to the CS+ (McTeague et al., 2015). Importantly, having both groups view the GCS allowed for the evaluation of the imagery to visual transfer as well as facilitate the comparison of imagined and perceptual generalization gradients. The secondary aim of this study was to evaluate the persistence of fear generalization following a period of consolidation without the continued delivery of the US. As such, participants returned to the lab the following day and completed the generalization phase again, devoid of US presentation, which we refer to as the Generalization Recall phase. Participants' fear toward the CSs were assessed via the dependent measures of self-report and SCR. The primary hypothesis for this study was that, during the Generalization Phase on day one, participants in the Imagery group would demonstrate a greater CR GCS in comparison to the perception group.

Method

Participants

98 participants (47 female, 50 male, and 1 individual that did not identify on a gender binary; 94% 18-24 years old) were recruited through the University of Manitoba's department of psychology subject pool (SONA) system, provided informed consent, and received credits as compensation for their participation. We report the Age of the sample as a range because the age of each participant was captured through age range options, rather than a specific input of the participant's age. Each participant was randomly assigned to be in the Imagery (N = 48) or Visual group (N = 50). This study was not pre-registered. Participants were excluded from the study if they had a neurological condition (e.g., stroke, dementia), psychological conditions (e.g., clinically diagnosed depression, anxiety, schizophrenia), history of mental illness, significant head trauma, alcohol or drug dependence, pacemaker, or pregnancy (Burleigh et al., 2022). Participants were excluded from the analysis if they did not display a detectable SCR response to the US (Lonsdorf et al., 2017), or if participants did not comply to the instructions of the experiment. A detectable SCR response to the US was identified through visual inspection after filtering the data. A non-detectable response was noted if the data had high-frequency noise, large spikes, and/or sudden drops in signal that would make it too difficult to differentiate between noise and an SCR response, even to the US (Burleigh et al., 2022).

A review of similar fear generalization research (Dunsmoor et al., 2017; Dunsmoor & LaBar, 2013; Starita et al., 2019), as well as mental imagery and fear conditioning research (Burleigh et al., 2022; Jiang & Greening, 2021), was consulted to determine the sample size for the current study. Between these studies, a sample size of 20 to 56 participants per group was noted. Importantly, as this was a two-day study, a level of attrition needed to also be accounted for in the sample estimation. Based on these factors and potential exclusions, the maximum target sample per group was 50 participants, with the goal of having a final sample above 45 participants for each group. This study was approved by the Research Ethics Board at the University of Manitoba, Fort Garry campus.

During the Acquisition phase, self-report data were available for 96 participants (49 visual; 47 imagery), due to two participants not complying to the instructions of the experiment (i.e., not completing the trial-by-trial self-report requirement, and/or exhibiting disruptive behaviours such as cellphone use that did not cease after experimenter requests). Additionally, for Acquisition, SCR data were available for 93 participants (47 visual; 46 imagery), due to two participants having non-detectable SCR, two participants having technical difficulties, and one participant not complying to the instructions. During the Generalization phase, self-report data were available for 97 participants (49 visual; 48 imagery), due to one participant not complying with the instructions. Furthermore, SCR data were available for 93 participants (46 visual; 47 imagery), due to three participants having non-detectable SCR, one participant having technical difficulties, and one participant not complying with instructions. During the Generalization Recall phase, self-report data were available for 90 participants (43 visual; 47 imagery), due to seven participant no-shows and one participant not complying with instructions. Furthermore, this phase had a sample of 80 for SCR analysis (37 visual; 43 imagery), due to five participants having non-detectable SCR, seven participant non-shows, five participants having technical difficulties, and one participant not complying to the instructions.

Materials

This task was created in MATLAB. During the experiment, white Gabor-like line patches oriented at either 45 degrees (line patches that begin from the lower left to the upper right) or 135 degrees (line patches that begin from the lower right to the upper left) were presented against a black background on a computer screen 55cm away from the participant and within 8 degrees of visual angle in the center of the screen. These stimuli were used as the CS+ and CS-. Across participants, counterbalancing reversed these stimuli (CS+ = 45° or 135°; CS- = 135° or 45°). Audio instructions were given only to participants in the Imagery group as an indication of their CS+ and CS- onset. The instructions given were *imagine right* (CS+; counterbalanced CS-) or *imagine left* (CS-; counterbalanced CS+) and created with a text-to-speech generator (www.fromtexttospeech.com; Burleigh et al., 2022). Throughout the experiment, participants viewed additional white line patches ranging +/- 10, 20, and 30 degrees from the CS+, such that when the CS+ is 45°, the generalization stimuli (GS) will be: 15° (GS-30), 25° (GS-20), 35° (GS-10), 55° (GS+10), 65° (GS+20), and 75° (GS+30). Alternatively, when the CS+ was counterbalanced at 135°, the generalization stimuli were: 105° (GS-30), 115° (GS-20), 125° (GS-10), 145° (GS+10), 155° (GS+20), and 165° (GS+30).

At the end of each trial, participants in both groups answered the question, "*How afraid of the shock were you?"*, on a 7-point Likert scale, ranging from 1 (*not at all*) to 7 (*very much so*). For descriptive purposes, participants also completed the Vividness of Visual Imagery questionnaire (Marks, 1973).

The US was somatosensory stimulation (i.e., mild shock) delivered via two electrodes (one per finger) that were placed on the tips of the pinky and ring fingers of the non-dominant hand of participants. The US was administered using the STMISOC and STM100C modules of BIOPAC (Jiang & Greening, 2021). Before beginning the task, participants underwent a thresholding procedure in which they are exposed to incremental increases of shock intensities until they reached an intensity that they felt was *uncomfortable*, *but not painful*.

Psychophysiological Measures

Skin Conductance Response: Electrodermal Activity, from which the SCR is extracted, was measured by placing two Ag/AgCl electrodes (one per finger) with conductive gel (BIOPAC GEL101) on the index and middle fingers of the non-dominant hand of participants. SCRs were recorded in Acq*Knowledge* at a 2000-Hz sample rate (Burleigh et al., 2022; Jiang et al., 2021). In order to control for SCR drift, the timeseries for each phase was preprocessed with a Butterworth bandpass filter, cutting off the frequencies above 5 Hz and below 0.01 Hz. Finally, the timeseries were downsampled to 100 Hz.

SCRs were calculated by subtracting a maximum value during CS presentation and a minimum value during baseline. Specifically, minimum baseline recordings were calculated one second before and after CS onset; maximum recordings were be recorded between a 1- to -5.5-s time window following CS onset. This value was then square-root transformed to increase normality prior to analysis (Burleigh et al., 2022). An SCR that did not cross a 0.02 μS threshold was set to zero (Jiang et al., 2021).

Procedure

This experiment spanned two days. On day one, there was three phases: Habituation, Acquisition, and Generalization. On day two, there was only the Generalization Recall phase.

Before the task began, both groups underwent a habituation run to become familiar with the experimental stimuli and procedure, devoid of the US. This habituation run had 8 total trials, including 2 CS+ view, 2 CS+ imagine, 2 CS- view, and 2 CS- imagine.

For the perception group trials, each began with a white fixation dot for 2 seconds; whereas the imagine group trials viewed the fixation dot for 3.5 seconds as they received auditory instructions during this time, such as “imagine left” or “imagine right.” For the perception group trials, this white dot then turned grey simultaneously with the presentation of the Gabor patch, lasting for 6 seconds. Conversely, for the imagine group trials, the white dot turned grey to indicate that participants should imagine the Gabor patch, lasting for 6 seconds. Finally, both groups were asked the Likert question and had 6 seconds to indicate their level of fear via keyboard entry. After these 6 seconds, the white fixation dot reappeared for 2 to 4 seconds, before the next trial began with a 2 second fixation dot. Taken together, the inter-trial interval was between 10 and 12 seconds.

Acquisition phase: During the Acquisition phase, participants completed 24 trials of differential fear conditioning (Figure 1). The general trial structure and timing were the same as in habituation with the exception of having the US delivered occasionally as specified below. Dependent on group assignment, participants either viewed or imagined the CS+ and CS-. During half the CS+ trials, participants received a mild shock for 500 milliseconds when the Gabor and the grey dot ended at 5.5 seconds. If the trial was a CS+ without shock or a CS- trial, participants imagined or attended to the Gabor patch for 6 seconds. The trial order was pseudorandom. Specifically, the first trial was always a CS- and the second trial was always a CS+ with shock. These two trials were followed by a random order of 10 trials, which contained two more CS+ with shock. The next 12 trials remained random and contained three CS+ trials with shock. The first CS+ and CS- trial for each participant were excluded from the analysis, as these trials may have displayed erroneous results due to an orienting effect (Burleigh et al., 2022). After each trial, participants answered the Likert question. To avoid having the physical US affect self-reported rating, all self-report ratings for the CS+ trials that co-terminated with shock were excluded from the analysis.

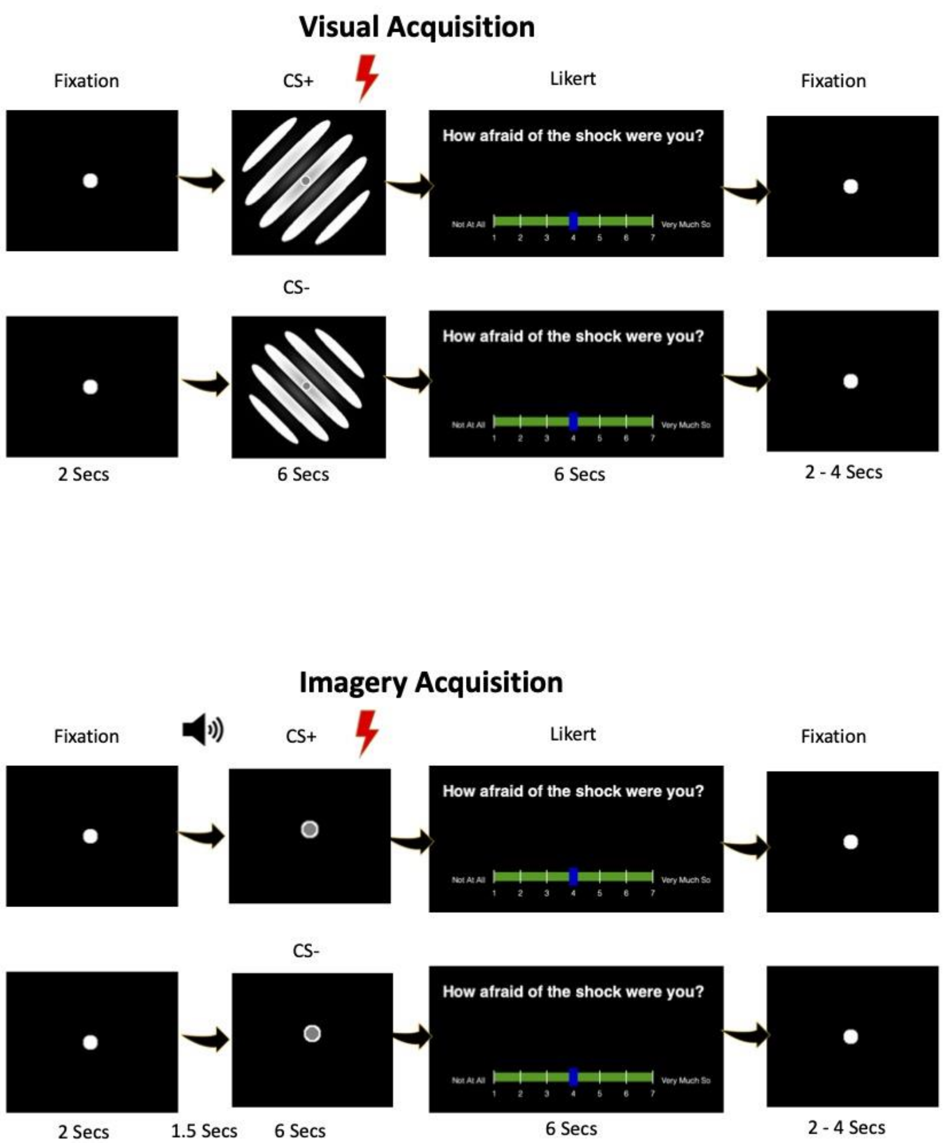

Figure 1: Acquisition Phase for both the Visual and Imagery groups.

Generalization phase: Still on day one, participants completed 48 trials in the Generalization phase. Overall, participants in both groups viewed all six GS orientations (GS+/-10, GS+/- 20, GS+/- 30) along with the CS+ and CS- four times (Figure 2). Furthermore, dependent on group assignment, participants also underwent additional booster trials in which they viewed or imagined the CS+ and CS- eight times, with four of the CS+ trials containing the US to prevent extinction learning. For the Imagery group booster trials, participants were instructed to imagine either the CS+ or CS-; for the Visual group booster trials, participants continued to view the CS+ and CS-. The booster CS+ trials in the visual group were yoked to the Imagery group, such that the location of the boosters between the two groups were identical. The trial order was pseudorandom. For every 12 trials, participants viewed one: CS+, CS-, and each GS; as well as view or imagine two CS+ (50% shock) and CS- as booster trials. Participants continued to answer the Likert question at the end of each trial.

Generalization Recall phase: On day two, participants returned to the lab and completed the Generalization Recall phase, which was identical to the day one Generalization phase with the notable expectation that participants received no booster trials with shock. In this way, participants completed 48 new pseudorandom trials, with all stimuli and recording devices remaining the same. However, diverging from day one, participants did not indicate their preferred threshold to the shock. Instead, participants were told the shock was the same threshold they identified on day one.

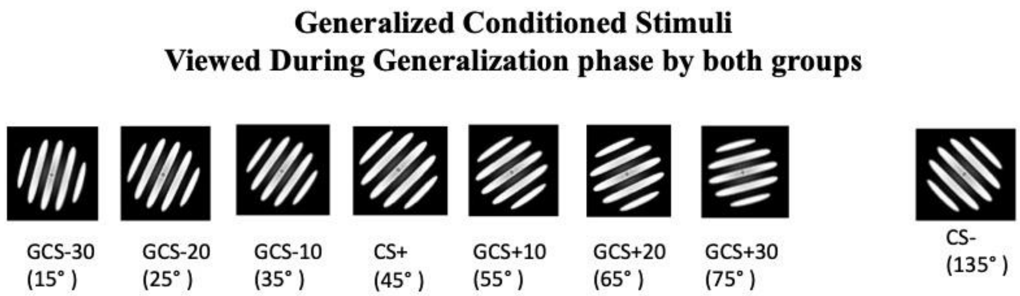

Figure 2: Generalization Phase stimuli. Counterbalancing switched the CS- and CS+ orientations.

Analysis

No outlier removal was conducted. Mixed repeated measures analysis of variance (ANOVA) was used for each phase and each dependent measure. Greenhouse-Geisser corrections were applied when the assumption of sphericity was violated. Finally, to assess main effects and interactions, paired sample *t*-tests without corrections were undertaken (Jiang & Greening, 2021).

Results

Demographic Differences Between Groups

Overall, there were no significant differences between the two groups for the VVIQ, $t(96) = -1.19$, $p = .237$, $d = 0.24$; age, X^2 = (df = 3, N = 98), 2.13, $p = .545$; or, gender identity, X^2 = (df = 2, N = 98), 1.57, $p = .456$.

Acquisition Phase

Self-Reported Fear of Shock

To determine whether differential fear conditioning was achieved during the Acquisition Phase, a 2 (CS type: CS+ vs. CS-) x 2 (Group: Imagery vs. Visual) mixed ANOVA was conducted (Figure 3A). A significant main effect of CS Type was observed, $F(1, 94) = 16.66$, $p < .001$, $\eta p^2 = .151$. There was no significant main effect of Group $F(1, 94) = 0.04$, $p = .844$, $\eta p^2 < .001$; nor was there a significant interaction, $F(1, 94) = 0.001$, $p = .972$, $\eta p^2 < .001$. In the Visual group, paired sample *t*-tests revealed a significant result for differential fear conditioning between the CS+ and CS-, $t(48) = 3.1$, $p = .004$, $d = 0.44$. Similarly, in the Imagery group, there was a significant difference between the CS+ and CS-, $t(46) = 2.73$, $p = .009$, $d = 0.40$. Collectively, these results suggest that differential fear conditioning was achieved for both groups.

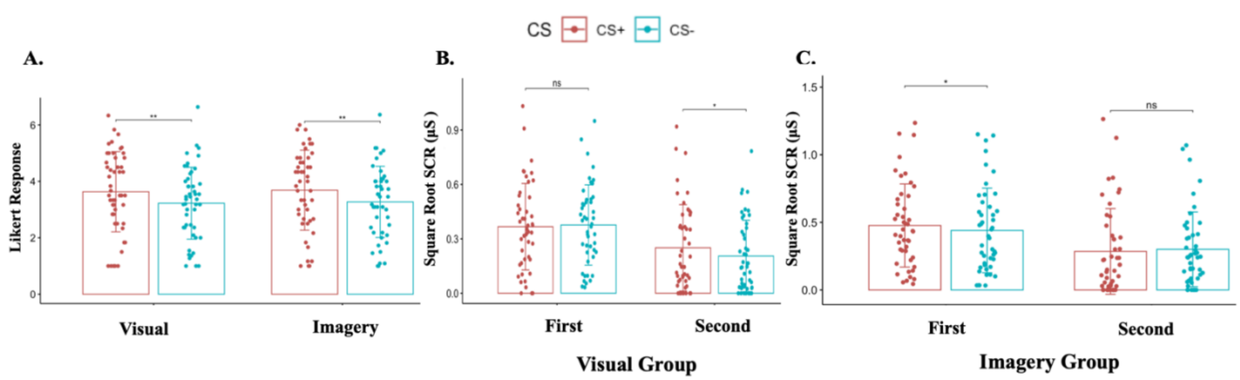

Figure 3. Results of the Acquisition Phase. (a) The self-reported fear of each participant in the Acquisition Phase. Results are separated between the Visual group and the Imagery group; (b, c) The square-root SCR in microsemiens for the Visual group (b) and Imagery group (c) seperated between the first half and second half of the Acquisition Phase after excluding the first two trials (one CS-, and one CS+). Thus, the first half includes five trials, the second half includes six trials. In each graph, the bars represent the mean response, error bars represent the 95%

confidence intervals, and the dots represent individual participant data points. *$p < .05$. **$p < .01$ (the * in (C) denotes one-tailed significance).

Skin Conductance Response

The same ANOVA was conducted for SCR during the Acquisition Phase. There was no significant main effect of CS Type, $F(1, 91) = 1.83$, $p = .180$, $\eta p^2 = .020$; Group, $F(1, 91) = 2.10$, $p = .150$, $\eta p^2 = .023$; nor was there an interaction effect, $F(1, 91) = 0.34$, $p = .563$, $\eta p^2 = .004$. To assess how learning may have developed over time, an exploratory analysis split the Acquisition Phase into two blocks (Schiller et al., 2010). A 2 (Group: Visual vs. Imagery) x 2 (CS Type: CS+ vs. CS-) x 2 (Time: First vs. Second) ANOVA was conducted. There was a main effect of Time, $F(1, 91) = 134.63$, $p = < .001$, $\eta p^2 = .597$; as well as a Group x CS Type x Time interaction, $F(1, 91) = 6.77$, $p = .011$, $\eta p^2 = .069$. To explore this three-way interaction, paired sample *t*-tests were conducted. In the Visual group, no significant difference between the CS+ and CS- was found in the first block of the phase, $t(46) = -0.54$, $p = .594$, $d = 0.08$. However, there was a significant differential in the second block, $t(46) = 2.36$, $p = .023$, $d = 0.34$ (Figure 3B). Conversely, the Imagery group demonstrated an opposite effect, whereby learning took place in the first block of the phase as demonstrated with one-tailed significance, $t(45) = 1.78$, $p = .041$, $d = 0.26$. However, this differential response dissipated in the second block of the phase, $t(45) = -0.62$, $p = .269$, $d = 0.09$ (Figure 3C).

Taken together, these SCR results partially corroborate the self-report findings. Specifically, differential fear expression was observed in both groups. However, diverging from the self-report results, SCR responses were sensitive to time.

Generalization Phase Day 1

Overall Self-Reported Fear of Shock on Booster Trials

Fear of shock ratings for the booster trials were evaluated to examine the presence of differential fear throughout the Generalization Phase. There was a significant main effect of CS Type, $F(1,95) = 18.25$, $p < .001$, $\eta p^2 = .161$. No other significant results were found (Table 1). In the Visual group, paired sample *t*-tests revealed differential fear between the CS+ and CS-, $t(48) = 2.55$, $p = .014$, $d = 0.36$. Similarly, in the Imagery group, there was a significant difference between the CS+ and CS-, $t(47) = 3.42$, $p = .001$, $d = 0.49$. Overall, these results suggest that differential fear conditioning was maintained by both groups throughout the Generalization Phase.

Table 1: ANOVA Self-Report Results for Boosters Trials during Generalization Phase

	df	df	F	Sig.	Partial Eta Squared
B Type	1	95	18.253	<.001	.161
Group	1	95	0.544	.463	.006
B Type*Group	1	95	1.112	.294	.012

Overall Self-Reported Fear of Shock on Generalization Phase Trials

For exploratory purposes and to remain consistent with the Acquisition Phase, self-reported fear during the Generalization Phase was evaluated across time with a 2 (Group: Visual vs. Imagery) x 5 (Orientation: CS+ vs. CS- vs. GCS +/- 10 vs. GCS +/- 20 vs. GCS +/- 30) x 4 (Time: Block 1 vs. Block 2 vs. Block 3 vs. Block 4) ANOVA. Due to missing observations, 13 participants were not included in this ANOVA with Time as a factor. A main effect of Time was observed, $F(2.41, 197.43) = 7.97$, $p < .001$, $\eta p^2 = .089$; as well as a main effect of Orientation, *F*(2.40, 196.40) = 7.65, $p < .001$, $\eta p^2 = .085$. However, no significant interaction effects were found between Time, Orientation, or Group (Table 2).

As the previous ANOVA uncovered no interactions with Time but required the exclusion of 13 participants, we conducted a 2 (Group: Imagery vs. Visual) x 5 (Orientation: CS+ vs. CS- vs. GCS +/- 10 vs. GCS +/- 20 vs. GCS +/- 30) mixed ANOVA (Figure 5A). This analysis allowed us to evaluate our planned primary hypothesis regarding the effects of Orientation. There was no significant interaction between Orientation and Group, *F*(2.65, 251.85) = 0.42, *p* = .715, $\eta p^2 = .004$. However, there was a significant main effect of Orientation, *F*(2.65, 251.85) = 8.30, $p < .001$, $\eta p^2 = .080$. Paired sample *t*-tests revealed significant results for differential fear between the CS- and the CS+, *t*(96) = 3.80, $p < .001$, *d* = 0.39; the GCS+/- 10, *t*(96) = 3.71, $p < .001$, *d* = 0.38; the GCS+/- 20, *t*(96) = 2.92, *p* = .004, *d* = 0.30; and the GCS+/- 30, *t*(96) = 2.53, *p* = .013, *d* = 0.26. Additionally, when comparing the CS+ and GCS to each other, paired *t*-tests indicated a significant difference between both the CS+ and GCS+/- 20, *t*(96) = 2.28, *p* = .025, *d* = 0.23; as well as the GCS+/- 30, *t*(96) = 2.55, *p* = .012, *d* = 0.26. The GCS+/- 10 was significantly different from the GCS+/- 30, *t*(96) = 2.53, *p* = .013, *d* = 0.26. Finally, there was a significant main effect of Group, *F*(1, 95) = 6.45, *p* = .013, $\eta p^2 = .064$, such that the Visual group had on average significantly higher self-reported fear.

Notably, the a priori hypothesis of imagined fear transferring to the same visual stimulus was tested on only the Imagery group. Paired sample *t*-tests for the Imagery group demonstrated a significant transfer of differential fear, such that viewing the CS+ was significantly greater than viewing the CS-, *t*(47) = 3.16, *p* = .003, *d* = 0.46. Likewise, compared to viewing the CS-, participants reported significantly higher fear of shock when viewing the GCS+/- 10, *t*(47) = 2.85, *p* = .006, *d* = 0.41; and the GCS+/- 20, *t*(47) = 2.47, *p* = .017, *d* = 0.36. No significant difference was found for the GCS+/- 30, $t(47) = 1.61$, $p = .114$, $d = 0.23$, in relation to the CS-. Therefore, a significant transfer of fear for participants in the Imagery group was observed, along with a generalization of this transferred fear.

Table 2: ANOVA Self-Report Results by Orientation, Time, and Group during Generalization Phase

	df	df	F	Sig.	Partial Eta Squared
Orientation	2.40	196.40	7.647	<.001	.085
Group	1	82	4.226	.043	.049
Orientation*Group	2.40	196.40	0.803	.469	.010
Time	2.41	197.43	7.972	<.001	.089
Time*Group	2.41	197.43	0.238	.827	.003
Orientation*Time	8.86	726.75	0.858	.561	.010
Orientation*Time*Group	8.86	726.75	1.332	.217	.016

Note. Greenhouse-Geisser Correction.

Skin Conductance Response

Booster Trials

Analysis of the Generalization Phase booster trials revealed that there was no significant main effect of CS Type, $F(1, 91) = 0.13$, $p = .721$, $\eta p^2 = .001$, nor a significant interaction between Orientation and Group, $F(1, 91) = 0.11$, $p = .741$, $\eta p^2 = .001$. However, there was a significant main effect of Group, $F(1, 91) = 9.11$, $p = .003$, $\eta p^2 = .091$, such that the Imagery group demonstrated a significantly higher SCR regardless of CS Type. Additionally, for the booster trials, adding time as a factor resulted in the main effects of Time, $F(2.53, 229.76) = 5.17$, $p = .003$, $\eta p^2 = .054$; and Group, $F(1, 91) = 9.30$, $p = .003$, $\eta p^2 = .093$. However, no interactions between Time (Block 1 vs. Block 2 vs. Block 3 vs. Block 4), Type (CS+ vs. CS-), or Group (Visual vs. Imagery) were found (Table 3). Therefore, diverging from the self-report, the SCR booster results did not show a specific response.

Table 3: ANOVA SCR Results by Booster Type, Time, and Group during Generalization Phase

	df	df	F	Sig.	Partial Eta Squared
Type	1	91	0.448	.505	.005
Group	1	91	9.297	.003	.093
Type*Group	1	91	0.015	.901	<.001
Time	2.53	229.76	5.171	.003	.054
Time*Group	2.53	229.76	0.675	.543	.007
Type*Time	2.87	261.50	0.202	.888	.002
Type*Time*Group	2.87	261.50	0.994	.394	.011

Note. Greenhouse-Geisser correction.

Generalization Trials

Each block in the Generalization Phase had one trial for each orientation, along with two trials for both booster types. Different from the Acquisition Phase, the first trial of the Generalization Phase was random. Exploratorily, the SCR during fear generalization was evaluated across time with a 2 (Group: Visual vs. Imagery) x 5 (Orientation: CS+ vs. CS- vs. GCS +/- 10 vs. GCS +/- 20 vs. GCS +/- 30) x 4 (Time: Block 1 vs. Block 2 vs. Block 3 vs. Block 4) ANOVA. There was a significant main effect of Time, $F(2.74, 249.03) = 33.45$, $p < .001$, $\eta p^2 = .269$, as well as a Time x Orientation interaction, $F(8.47, 771.15) = 3.29$, $p < .001$, $\eta p^2 = .035$. There were no other significant results (Table 4). To investigate the effects of Time, we averaged across all other factors and performed pairwise comparisons, which revealed that the first block of the Generalization Phase was significantly higher than all other blocks ($p < .001$). The other three blocks (Block 2, Block 3, Block 4) did not differ significantly from every other block. Specifically, Block 2 did not differ from Block 3 ($p = .296$), Block 3 did not differ from Block 2 ($p = .296$) or Block 4 ($p = .087$), and block 4 did not differ from Block 3 ($p = .087$). This pattern suggested that potential orienting and novelty effects were present during this phase (Lim &

Pessoa, 2008; Schiller et al., 2010). Consequently, the primary analysis of SCR focused on the final 3 blocks of the Generalization Phase (Figure 4).

Table 4: ANOVA SCR Results by Orientation, Time, and Group during Generalization Phase

	df	df	F	Sig.	Partial Eta Squared
Orientation	**3.44**	**312.98**	1.217	.304	.013
Group	1	91	0.046	.831	.001
Orientation*Group	**3.44**	**312.98**	0.314	.841	.003
Time	**2.74**	**249.03**	33.448	<.001	.269
Time*Group	**2.74**	**249.03**	1.114	.341	.012
Orientation*Time	**8.47**	**771.15**	3.288	<.001	.035
Orientation*Time*Group	**8.47**	**771.15**	0.831	.581	.009

Note. Greenhouse-Geisser correction.

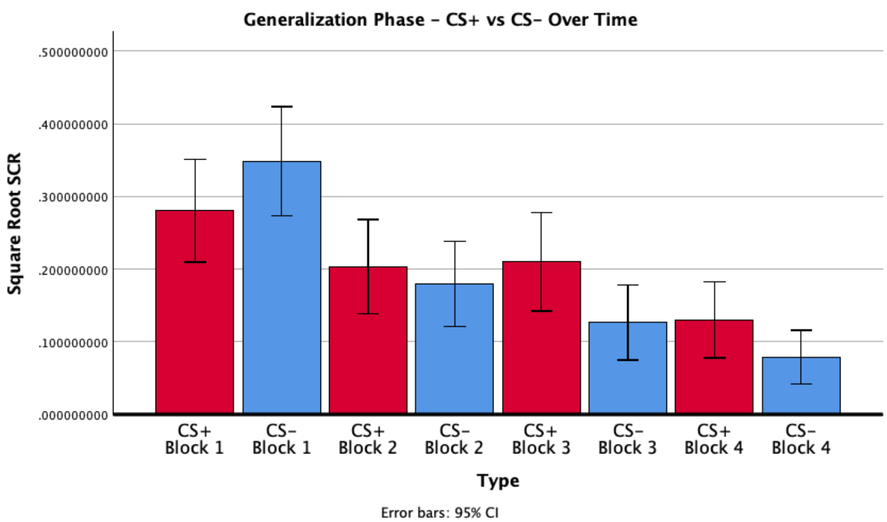

Figure 4: SCR of the Generalization Phase for CS+ and CS- by each block. Notably, the Block 1 CS- flips to being lower than the CS+ for the rest of the phase, indicative of an orienting effect.

The results of the planned analysis of the SCR entailed a 2 (Group: Imagery vs. Visual) x 5 (Orientation: CS+ vs. CS- vs. GCS +/- 10 vs. GCS +/- 20 vs. GCS +/- 30) mixed ANOVA, which partially corroborated the self-report data with the significant main effect of Orientation, $F(3.50, 318.89) = 2.81$, $p = .032$, $\eta p^2 = .030$ (Figure 5C). However, there was no significant interaction between Orientation and Group, $F(3.50, 318.89) = 0.35$, $p = .822$, $\eta p^2 = .004$, or main effect of Group, $F(1, 91) = 0.19$, $p = .662$, $\eta p^2 = .002$. To assess the main effect of Orientation, follow-up paired sample *t*-tests were conducted on each of the orientations with the Visual and Imagery groups combined. These tests revealed a significant result of differential fear between the CS- and both the CS+, $t(92) = 2.48$, $p = .015$, $d = 0.26$ and the GCS+/-30, $t(92) = 2.48$, $p = .015$, $d = 0.26$. Additionally, the CS+ was significantly higher than the GCS+/- 10, $t(92) = 2.14$, $p = .035$, $d = 0.22$.

To evaluate the a priori hypothesis of differential fear transferring from imagined to visual trials, follow up t-tests for the Imagery group were conducted on the visual CS+ and CS- (Burleigh et al., 2022). These tests demonstrated a significant transfer of imagined fear for the CS+, $t(46) = 2.16$, $p = .036$, $d = 0.32$, relative to the CS- (Figure 5D). Ultimately, these results support the self-report data for the Imagery group as both imagined and perceptual fear generalization reacted in a similar way.

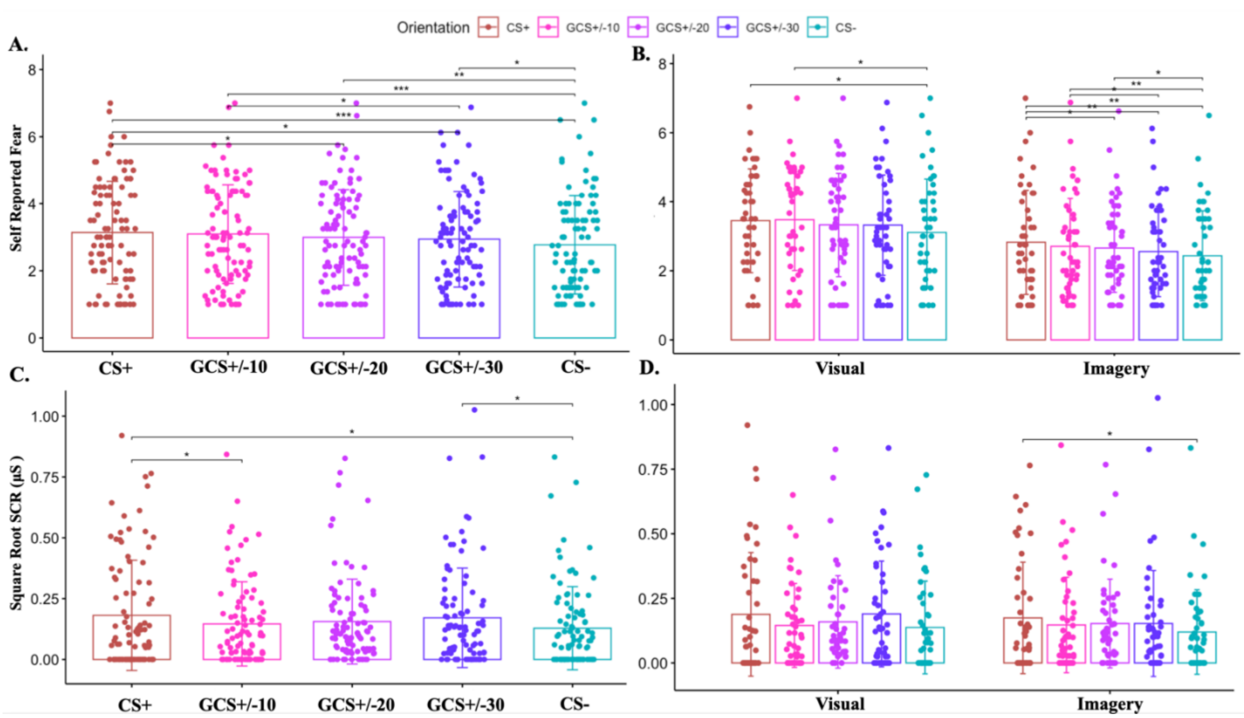

Figure 5. Results of the Generalization Phase (a) The self-reported fear of each participant in the Generalization Phase; (b) The self-reported fear of each participant in the Generalization Phase, separated between the Visual group and the Imagery group; (c) The square-root SCR in microsemiens for the Generalization Phase; (d) The square-root SCR in microsemiens for the Generalization Phase, seperated between the Visual group and the Imagery group. In each graph, the bars represent the mean response, error bars represent the 95% confidence intervals, and the dots represent individual participant data points. $*p < .05$. $**p < .01$, $*** p < .001$.

Generalization Recall Phase Day 2

Self-Reported Booster Trials

For the Generalization Recall Phase, the "booster" trials were analyzed in the same manner as the ANOVA was conducted for booster trials as in the Generalization Phase (Figure 6A). However, in the Generalization Recall Phase the "booster trials" no longer included the US on any trials. There was a significant main effect of CS Type, $F(1, 88) = 19.12$, $p < .001$, $\eta p^2 = .18$. There was no significant interaction between CS Type and Group, $F(1, 88) = 3.52$, $p = .064$, $\eta p^2 = .04$, nor a significant main effect of Group, $F(1,88) = 0.328$, $p = .568$, $\eta p^2 = .004$. Follow up paired sample t-test releveled both the Visual group, $t(42) = 2.14$, $p = .038$ $d = 0.33$; and the Imagery group, $t(46) = 3.94$, $p < .001$, $d = 0.57$, demonstrated a significant differential between their respective CS+ and CS- even with no shocks administered.

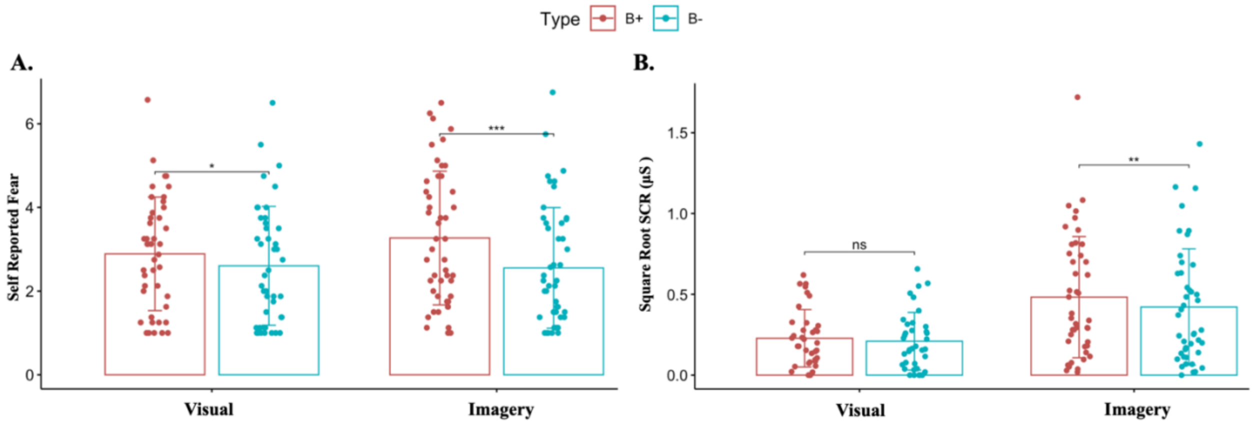

Figure 6. Results for Generalization Recall Phase booster trials. (a) The self-reported fear of each participant in the Generalization Recall Phase for booster trials, seperated by the Visual group and Imagery group; (b) The square-root SCR in microsemiens for the Generalization Recall Phase for each participant, separated between the Visual group and the Imagery group. In each graph, the bars represent the mean response, error bars represent the 95% confidence intervals, and the dots represent individual participant data points. **p* < .05. ***p* < .01, *** *p* < .001.

Self-Reported Generalization Recall Trials

Overall, there was no significant interaction between Orientation and Group, $F(2.88, 253.03) = 0.59$, $p = .615$, $\eta p^2 = .007$. Additionally, there was no significant main effect of Orientation, $F(2.88, 253.03) = 0.52$, $p = .659$, $\eta p^2 = .006$. However, there was a significant main effect of Group, $F(1, 88) = 5.72$, $p = .019$, $\eta p^2 = .061$, such that the ratings for the Visual group were significantly higher than the Imagery group.

For exploratory purposes and to assess early and late extinction trends, the same 2 (Group: Visual vs. Imagery) x 5 (Orientation: CS+ vs. CS- vs. GCS +/- 10 vs. GCS +/- 20 vs. GCS +/- 30) x 4 (Time: Block 1 vs. Block 2 vs. Block 3 vs. Block 4) ANOVA was conducted. A main effect of Time was found, $F(2.11, 160.01) = 26.26$, $p < .001$, $\eta p^2 = .260$; along with a significant Time x Group interaction, $F(2.11, 160.01) = 3.74$, $p = .024$, $\eta p^2 = .047$. Specifically, regarding the Imagery group, results of Orientation appeared to differ over Time (Figure 7A); this was particularly evident from the first and second blocks of time to the third and fourth blocks of time. When combining the first and second blocks together and the third and fourth blocks together, paired sample *t*-tests revealed that Imagery group participants in the combined third and fourth blocks demonstrated a one-tailed significant transfer of fear for the CS+, $t(46) = 2.01$, $p = .025$, $d = 0.29$; and GCS +/- 30, $t(46) = 1.77$, $p = .042$, $d = 0.26$, in relation to the second half CS-. Additionally, the CS+ was significantly higher (one-tailed) than the GCS+/-10, $t(46) = 1.98$, $p = .027$, $d = 0.29$.

Skin Conductance Response Booster Recall Trials

For the booster trials (Figure 6B), there was a significant main effect of CS Type, $F(1,78) = 8.15$, $p = .006$, $\eta p^2 = .095$. Additionally, there was a significant main effect of Group, $F(1, 78) = 12.94$, $p < .001$, $\eta p^2 = .142$, such that the SCR for the Imagery group were significantly higher than the Visual group. There was no interaction between CS Type and Group, $F(1, 78) = 2.37$, $p = .128$, $\eta p^2 = .029$. Follow up paired sample t-test indicated a significant result for the Imagery group, $t(42) = 2.99$, $p = .005$, $d = 0.46$; but not for the Visual group, $t(36) = 1.0$, $p = .324$, $d = 0.16$. In addition, to determine early and late trends, Time (Block 1 vs. Block 2 vs. Block 3 vs. Block 4) was included as a factor. A main effect of Time was found, $F(2.19, 170.89) = 60.49$, $p < .001$, $\eta p^2 = .437$. No interactions with Time were observed between Type and Group. Ultimately, consistent with self-report, when no shocks were administered, participants in the Imagery group still demonstrated a significant differential fear to the imagined CS+ and CS-.

Skin Conductance Response Generalization Recall Phase

Similar to the Generalization Phase, a 2 (Group) x 5 (Condition) x 4 (Time) ANOVA was conducted for exploratory purposes to determine the outlook of the Generalization Recall Phase.

There was a main effect of Time, $F(1.99, 155.23) = 51.66$, $p < .001$, $\eta p^2 = .398$; as well as a significant Group x Condition x Time interaction, $F(8.64, 673.71) = 2.14$, $p = .027$, $\eta p^2 = .027$. To further explore this three-way interaction, paired sample *t*-tests were conducted by group. For the Imagery group, the first block CS- is significantly higher than the first block CS+, $t(42) = -2.26$, $p = .029$, $d = 0.35$; similarly, the second block CS- stays significantly higher than the CS+, $t(42) = -2.91$, $p = .006$, $d = 0.44$. This differential then flips for the second half but not to a significant threshold in the third block, $t(42) = 1.38$, $p = .174$, $d = 0.21$; and the fourth block, $t(42) = 0.76$, $p = .452$, $d = 0.12$. Said another way, the booster trial analysis above demonstrated that the imagined fear of the CS+ was significantly higher than the CS-; however, the transferred fear of the CS+ and CS- had this unexpected phenomenon occur, whereby the visual CS- was significantly higher than the visual CS+ for the first two blocks of the phase. Indeed, the results for Generalization Recall Phase appear to be dependent on group and by the first and second half of the phase. When collapsing the four blocks into a first half (Blocks 1 and 2) and a second half (Blocks 3 and 4), only the transferred CS+ for the Imagery group was not significantly different from the first to second half of the phase, $t(42) = -0.56$, $p = .582$, $d = 0.09$. In contrast, all other conditions, for both groups, demonstrate a significant decrease from the first half to the second half (see Table 5; Table 6). Furthermore, for the Imagery group, the first half transferred CS+ was significantly lower than the GCS+/-10, $t(42) = -2.47$, $p = .018$, $d = 0.38$; and GCS30+/-, $t(42) = -3.01$, $p = .004$, $d = 0.46$. Again, this differential flipped during the second half of the phase, as the transferred CS+ became significantly higher than the GCS+/- 10, $t(42) = 2.26$, $p = .029$, $d = 0.34$; and the GCS 30+/-, $t(42) = 2.29$, $p = .027$, $d = 0.35$.

Table 5: Visual Group Paired Samples Test for Generalization Recall Phase

First vs. Second Half Comparison	df	t	Sig.	d

CS+	36	4.192	<.001	0.689
CS-	36	4.824	<.001	0.793
GCS+/-10	36	3.729	<.001	0.613
GCS+/-20	36	6.067	<.001	0.997
GCS+/-30	36	4.691	<.001	0.771

Table 6: Imagery Group Paired Samples Test for Generalization Recall Phase

First vs. Second Half Comparison	df	t	Sig.	d
CS+	42	-0.55	.582	0.085
CS-	42	3.948	<.001	0.602
GCS+/-10	42	3.757	<.001	0.573
GCS+/-20	42	4.935	<.001	0.753
GCS+/-30	42	4.58	<.001	0.698

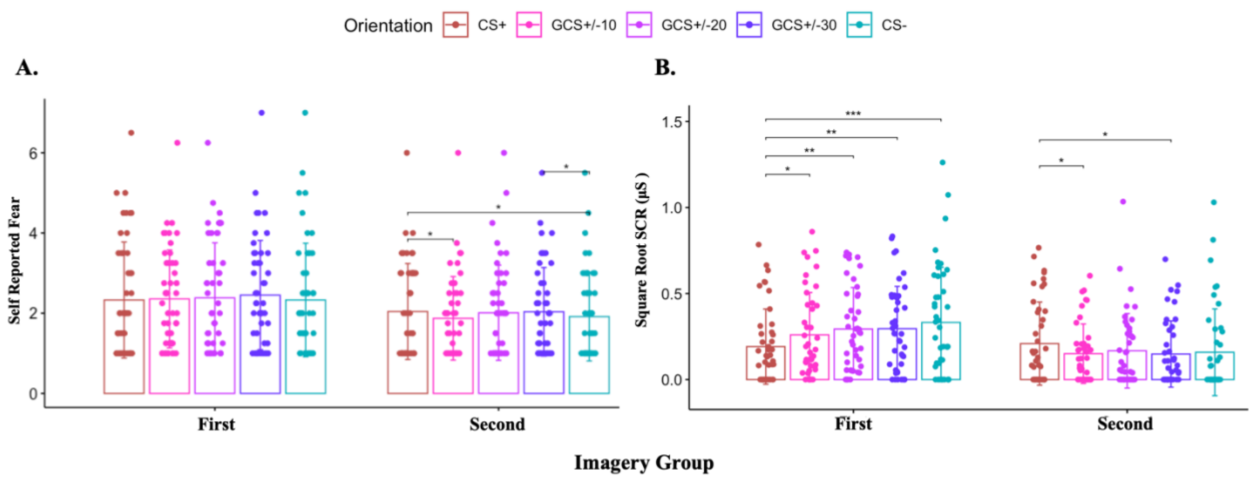

Figure 7: Results from the Generalization Recall Phase for the Imagery Group; (a) The self-reported fear of each participant in the Generalization Recall Phase, separated between the first half and second half; (b) The square-root SCR in microsemiens for each participant in the Generalization Recall Phase, seperated between the first half and second half of the Generalization Recall Phase. In each graph, the first half includes two trials for each orientation and the second half includes two trials for each orientation, the bars represent the mean response,

error bars represent the 95% confidence intervals, and the dots represent individual participant data points. *$p < .05$. **$p < .01$, *** $p < .001$ (the * in (A) denotes one-tailed significance).

Discussion

This two-day study investigated the generalization and persistence of differential fear conditioning acquired to imagined CSs, in comparison to the generalization of standard differential fear conditioning acquired to perceptual CSs. For both groups, self-report findings demonstrated successful fear conditioning toward the CS+ and CS- as well as a transfer of fear and subsequent generalization; no interaction effect was found between the groups. Self-report findings for the Generalization Recall phase suggested an unspecific persistence of fear in the first half of testing that extinguished for the Visual group but became specific to the CS+ for the Imagery group during the second half of the phase. Although SCR results were less clear, an acquisition of differential fear that generalized was observed; corroborating the self-report findings, no interaction effect was found between the groups. Notably, SCR findings demonstrated noticeable differences in generalization gradients when compared to self-report. SCR results for the Generalization Recall phase demonstrated a persistence of fear into the second day of testing only for the Imagery group that may have transferred during the second half of the phase. Taken together, in contrast to our primary hypothesis, the results from this study suggest that imagery-based fear conditioning generalizes to a similar extent as perceptually acquired fear conditioning, rather than demonstrating an overgeneralization effect. To our knowledge, this evidence of imagery-based fear generalization is the first of its kind.

Self-report data from the current investigation demonstrated that differential fear acquisition occurred for both the Visual and Imagery group. However, participants' SCR during the Acquisition phase appeared to be dependent on time. Specifically, whereas the Imagery group displayed a significant SCR differential in the first half of the phase, learning for the Visual group was delayed until the second half of the phase. This time effect was not predicted, as previous research comparing imagery-based fear conditioning to visual conditioning has not reported such a finding. Nevertheless, both measures suggest that a differential fear was learned for the Visual group; likewise, an imagined differential fear was formed for the Imagery group. This finding of fear acquisition to an imagined CS supports previous literature highlighting the similarities between mental imagery and perception (Burleigh et al., 2022; Burleigh & Greening, 2023).

Although not corroborated by SCR, self-report results of both groups' booster trials indicated a persistence of fear from the Acquisition phase to the Generalization phase. In addition, for the Imagery group, both the self-report and SCR results demonstrated that the acquired differential fear toward the imagined CS+ and CS- transferred to instances of viewing the corresponding visual CS+ and CS-. This finding of transfer replicates research that has observed a transfer of fear from an imagined CS+ to the corresponding visual CS+ (Burleigh et al., 2022; Burleigh & Greening, 2023). It is also consistent with previous research showing a transfer of fear from a visual CS+ to an imagined CS+ (Greening et al., 2022; Hoppe et al., 2021, 2022). More broadly, the finding of imagery-based fear conditioning and transfer to visual stimuli aligns with recent behavioural, neurological, and psychophysiological research describing mental imagery as being a mechanistically similar, yet attenuated process to perception (Mertens et al., 2020; Pearson, 2019; Pearson et al., 2011).

Of principal interest, the Generalization phase tested the possibility of imagery-based fears being more prone to generalization in comparison to perception-based fears. However, we observed no interaction in either self-report or SCR measures, which indicates no differences in the generalization gradients between the groups. Nevertheless, following a main effect of Orientation, we see strong evidence of generalization in self-reported fear across the two groups, as well as modest fear generalization between the GCS and CS- in SCR. Specifically, the self-report results displayed that fear had generalized to perceptually similar stimuli in a standard monotonic decay pattern (Dunsmoor et al., 2017; Dunsmoor & LaBar, 2013; Lissek, Bradford, et al., 2014), such that across groups, the CS+ and all three GCS were rated as significantly more fearful than the CS-. Moreover, the GCS+/-30 was significantly less fearful than both the CS+ and GCS+/-10, and the GCS+/-20 was less fearful than the CS+. As the Imagery group was of a priori interest we also evaluated group specific effects in participants' self-reported fear. Again, this analysis revealed a pattern consistent with a monotonic decay of self-reported fear in the Imagery group, which was also qualitatively more evident than in the Visual group. Nevertheless, this finding was not convincing enough to confirm our primary hypothesis that one suffers more in their imagination than reality. As such, results from the current study more so suggest that regardless of whether fear associations were achieved through mental imagery or perception, the degree of fear generalization occurs to the same extent.

It is noteworthy that we observed qualitatively distinct patterns of effect in the SCR results in the Generalization phase compared to those observed in the self-reported fear results discussed above. Specifically, whereas the self-report data showed a standard monotonic decay from CS+ to the GCSs to the CS-, the SCR data demonstrated a non-standard pattern of results. When collapsing across groups in the SCR, we unexpectedly observed that whereas the GCS+/-10 was significantly lower than the CS+, only the CS+ and the GCS+/-30 were significantly greater than the CS-. These SCR results might reflect a pattern of activation in subcortical regions such as the amygdala consistent with the phenomenon of lateral inhibition (Armony et al., 1997). Unlike the monotonic decay pattern often found in generalization, a lateral inhibition gradient demonstrates the lowest response to the most similar stimuli to the CS+, and as perceptual similarity decreases from the CS+, the response of the GCS increases. In other words, the GCS gradients appear inverted to one another. Prior fear conditioning studies have computationally modelled the necessity of lateral inhibition in the amygdala's receptive fields (Armony et al., 1997; Armony et al., 1995), as well as found activation in the inferotemporal cortex during fear generalization that are congruent with lateral inhibition (Onat & Büchel, 2015). Moreover, McTeague et al. (2015), from which our testing stimuli were adapted, found a standard CS+ to CS- decay in startle response which, importantly, may have been driven by lateral inhibition in the occipital lobe. While these two brain imaging studies (McTeague et al., 2015; Onat & Büchel, 2015) found evidence of lateral inhibition in regions of the brain related to sensation and perception, these same regions receive direct neural feedback from the amygdala (Freese & Amaral, 2005). However, to our knowledge, evidence for lateral inhibition as reflected in SCR data has not been widely reported in the literature. Further research is needed to assess the congruence or dissociation between these self-report and SCR measures.

Typically, researchers will employ several dependent measures such as self-report and SCR to fully understand the experience of fear (Burleigh et al., 2022). While some research exists demonstrating that these two measures may be correlated (Jiang et al., 2021), other researchers have observed that they may capture different aspects of fear (Clark & Squire, 1998; LeDoux, 2014). For example, one possibility is that our disparate findings during fear generalization are consistent with LeDoux's (1994) dual-process framework, which posits that the neural regions associated with the conscious experience of fear are somewhat distinct to the regions associated with the autonomic threat response. Reflecting this duality, research has suggested that the fear response may incorporate both conscious consideration, such as self-report, and autonomic physiological reactions, such as SCR (Grégoire et al., 2023; Mobbs et al., 2019). Speculatively, the qualitatively distinct generalization patterns observed in the self-reported fear versus SCR results of the present study might reflect this dual-framework dichotomy between conscious processes versus autonomic reactions, respectively.

The Generalization Recall phase assessed the persistence of imaginative fear without a US in comparison to the persistence of perceptual fear. Historically, fear generalization as measured using SCR and self-report has been studied through steady-state testing, where participants continue to receive the US intermittently during the generalization phase (Dunsmoor et al., 2009; Dunsmoor & LaBar, 2012; Lissek et al., 2014; Onat & Büchel, 2015). These so-called booster trials are included to defend against extinction and increase the total number of available test data before extinction occurs (Blough, 1975; Honig & Urcuioli, 1981). However, the ecological validity of steady-state procedures is likely low as this type of reinforcement may not be consistent with real-life fear. To our knowledge, our results from the Generalization Recall phase are the first attempt to fill this gap in the literature. Characteristic of canonical fear extinction, both our self-report and SCR results, for both groups, displayed a dissipation of fear from the first to second half. Notably, whereas self-report findings showed a significant differential for the CS+ and CS- in perceptual-based fear, both self-report and SCR results indicated that the imagery-based differential of fear persisted throughout the entire phase. These findings suggest that the acquired fear association from day one remained after a night of consolidation and was strongest for the Imagery group. Additionally, both self-report and SCR findings for imagery-based fear displayed a transfer of fear trend in the second half of the Generalization Recall phase. Unexpectedly, in SCR, this transfer occurred after the visual CS- was significantly higher than the visual CS+ in the first half of the phase. In comparison, perceptual-based fear never displayed a significant differential in the generalized testing stimuli during this non-steady-state day two. Tentatively, these data might suggest that imagined fear has unique qualities when tested after a consolidation period. One possibility is that imagery of the CS+ also implicitly facilitates imagined recall of the US (Greening et al., 2016; Olsson & Phelps, 2007). This inference, while speculative, would be consistent with previous research demonstrating that explicit imagery of both the CS+ and US simultaneously can produce fear conditioning (Krypotos et al., 2020; Yaremko & Weaner, 1974). If true, this speculation might help explain the stubbornness of imagery-based fears as found in several anxiety disorders (Hirsch & Holmes, 2007; Pearson et al., 2015).

Dovetailing these current findings with recent research, the similarity found between the groups may also elucidate a pernicious contribution of imagery to psychopathology. Indeed, research suggests that individuals with anxiety disorders ruminate on their fear associations via intrusive mental images (Hirsch & Holmes, 2007; Homer & Deeprose, 2017), and, in doing so, these fears have a greater opportunity to spread. The present findings suggest this generalization could occur to the same degree as perceptual fear generalization. Therefore, mental imagery may facilitate the maintenance and proliferation of an anxious individual's fear associations. Insidiously, this proliferation could occur at any time, as the physical presence of a feared stimulus is not needed for imagination.

Future research could build on these findings through several avenues. Indeed, results from the current study stem from participants who are free of mental health disorders. Therefore, if healthy participants demonstrate a generalization effect through mental imagery, perhaps individuals with anxiety related disorders have an accelerated form of this phenomenon. Future research could further differentiate groups based on participants with anxiety disorders and healthy control group individuals. This manipulation would help to examine whether anxious individuals demonstrate an imagery specific overgeneralization effect, similar to the overgeneralization found in fear conditioning studies utilizing in visual percepts (Lissek, Kaczkurkin, et al., 2014). Another avenue of exploration could be further manipulation of the stimuli. The current study, similar to McTeague et al. (2015), employed Gabor-like stimuli to each participant. However, participants in the current study were not explicitly instructed on which stimuli would be paired with shock and which stimuli would not be paired with shock, as done in McTeague et al (2015). In this way, the difference between the CS+ and CS- was simply the orientation of the same object and, thus, the safe stimuli (CS-) may have been ambiguous for participants. Future research could look to utilize stimuli that can be more easily differentiated, such as faces (Onat & Büchel, 2015).

Several considerations for the findings of this study should be noted. This study was not pre-registered, though our experimental procedures were consistent with other recent studies in the lab (e.g., Burleigh et al., 2022; Jiang and Greening, 2021) and based on the literature on fear generalization we consulted prior to the experiment. Additionally, although the present study opted to ask participants to rate their fear of shock trial-by-trial, future research on the role of mental imagery could benefit from alternative self-report assessments. For example, future research could have participants rate their shock expectancy trial-by-trial immediately following CS onset (Carter et al., 2006). It could also have participants rate their degree of fear or negative affect towards each CS per se rather than fear of shock (Sjouwerman et al., 2016).

Taken together, this study adds to the literature suggesting that mental imagery may be mechanistically similar to perception. Moreover, the results suggest that fear associations created through mental imagery may be as prone to fear generalization as those created through perception. Further, imagery-based fears appear unique in their extinction qualities following a period of consolidation. In other words, although the day one results suggest that one does not suffer more imagination than reality, the day two results provide tentative support that imagery-related fear is distinct from perceptually acquired fear.

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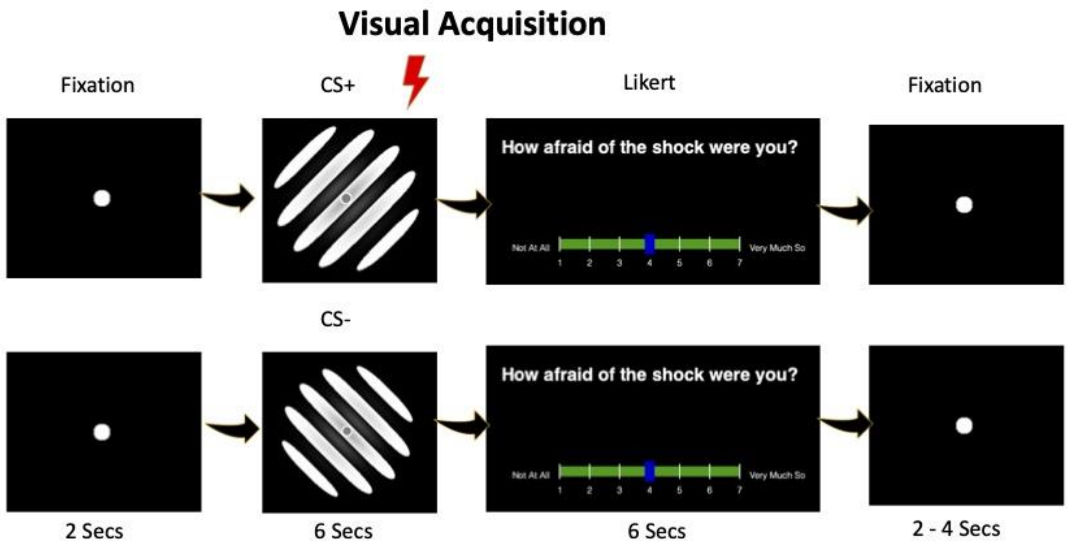
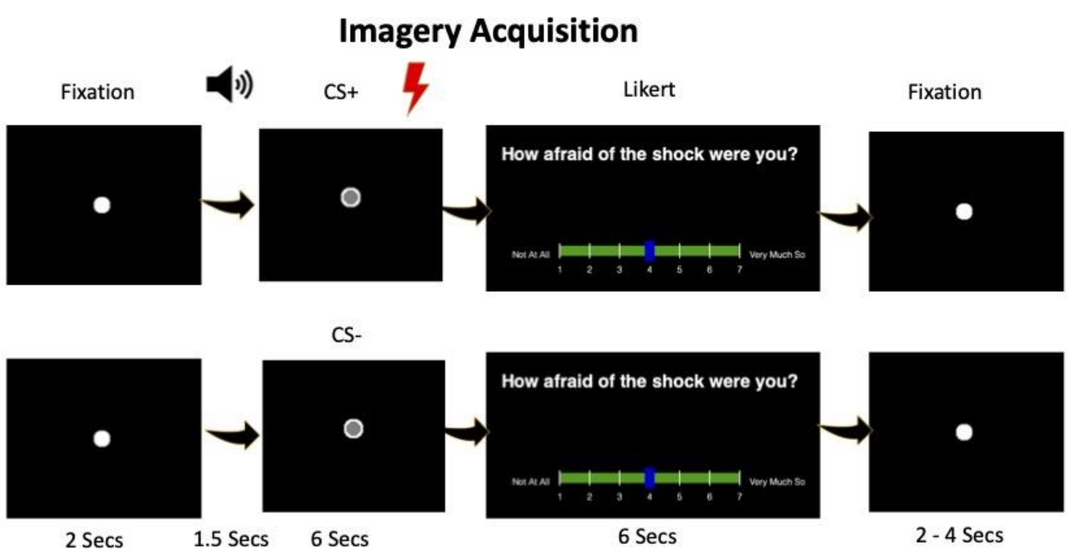
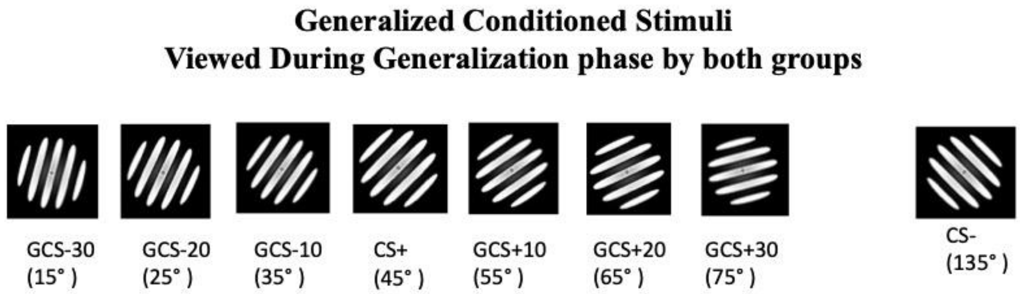
Supplemental Material
1. Methods







2. Experiment Results

2.1 Demographic

Measure:	**Mean**	**SD**
VVIQ	61.73	11.55

Table 1. Descriptive statistics of questionnaire administered before experiment.

2.2 Independent Samples Test for VVIQ by Group

	df	**t**	**Sig.**	**d**
VVIQ	96	-1.190	.237	0.240

2.3 Chi Square test for Demographics by Group

	df	**N**	**X^2**	**Sig.**
Gender Identity	2	98	1.572	0.456
Age	3	98	2.134	0.545

2.4 Self-reported Fear

2.4.1 Acquisition Phase

Descriptive Statistics

Table 2.1: Statistics of Self-Report Ratings by Group during Acquisition Phase

Stimuli	Visual Group		Imagery Group	
	M	*SD*	*M*	*SD*
CS+	3.63	1.4	3.69	1.4
CS-	3.23	1.3	3.27	1.3

Note. Larger scores equate to a stronger negative rating after stimulus was viewed. CS+ = conditioned stimulus paired with shock; CS- = conditioned stimulus not paired with shock.

2.4.1 ANOVA Results

Table 2.2: ANOVA Self-Report Results for CS Type by Group during Acquisition Phase

	df	df	F	Sig.	Partial Eta Squared
CS Type	1	94	16.658	<.001	.151
Group	1	94	0.039	.844	<.001
CS Type*Group	1	94	.001	.972	<.001

2.4.2 Generalization Phase

Descriptive Statistics

Table 2.3: Statistics of Self-Report Ratings by Group during Generalization Phase

Stimuli	Visual Group		Imagery Group	
	M	*SD*	*M*	*SD*
CS+	3.45	1.5	2.82	1.5
CS-	3.11	1.6	2.43	1.3
GCS+/-10	3.48	1.5	2.71	1.4
GCS+/-20	3.33	1.5	2.66	1.3
GCS+/-30	3.32	1.5	2.55	1.3
B+	3.46	1.4	3.80	1.7
B-	3.02	1.4	3.08	1.4

Note. Larger scores equate to a stronger negative rating after stimuli was viewed. CS+ = conditioned stimulus paired with shock; CS- = conditioned stimulus not paired with shock; GCS+/-10 = generalized conditioned stimulus 10-degrees from CS+; GCS+/-20 = generalized conditioned stimulus 20-degrees from CS+; GCS+/-30 = generalized conditioned stimulus 30-degrees from CS+; B+ = CS+ booster trials; B- = CS- booster trials.

2.4.2 ANOVA Results

Boosters Trial Results

Table 2.4: ANOVA Self-Report Results for Boosters Trials during Generalization Phase

	df	df	F	Sig.	Partial Eta Squared
B Type	1	95	18.253	<.001	.161
Group	1	95	0.544	.463	.006
B Type*Group	1	95	1.112	.294	.012

Generalization Phase Results

Table 2.5: ANOVA Self-Report Results by Orientation, Time, and Group during Generalization Phase

	df	df	F	Sig.	Partial Eta Squared
Orientation	2.40	196.40	7.647	<.001	.085
Group	1	82	4.226	.043	.049
Orientation*Group	2.40	196.40	0.803	.469	.010
Time	2.41	197.43	7.972	<.001	.089
Time*Group	2.41	197.43	0.238	.827	.003
Orientation*Time	8.86	726.75	0.858	.561	.010
Orientation*Time*Group	8.86	726.75	1.332	.217	.016

Note. Greenhouse-Geisser Correction.

Table 2.6: ANOVA Self-Report Results for during Generalization Phase

	df	df	F	Sig.	Partial Eta Squared
Orientation	2.65	251.85	8.295	<.001	.080
Group	1	95	6.449	.013	.064
Orientation*Group	2.65	251.85	0.419	.715	.004

Note. Greenhouse-Geisser Correction.

2.4.3 Generalization Recall Phase Results

Descriptive Statistics

Table 2.7: *Statistics of Self-Report by Group during Generalization Recall Phase*

Stimuli	Visual Group		Imagery Group	
	M	*SD*	*M*	*SD*
CS+	2.9	1.6	2.19	1.3
CS-	2.19	1.6	2.12	1.2
GCS+/-10	2.84	1.4	2.12	1.1
GCS+/-20	2.8	1.4	2.2	1.2
GCS+/-30	2.79	1.5	2.24	1.2
B+	2.89	1.4	3.27	1.6
B-	2.6	1.4	2.55	1.4

Note. Larger scores equate to a stronger negative rating after stimuli was viewed. CS+ = conditioned stimulus paired with shock; CS- = conditioned stimulus not paired with shock; GCS+/-10 = generalized conditioned stimulus 10-degrees from CS+; GCS+/-20 = generalized conditioned stimulus 20-degrees from CS+; GCS+/-30 = generalized conditioned stimulus 30-degrees from CS+; B+ = CS+ booster trials; B- = CS- booster trials.

2.4.3 ANOVA Results

Booster Stimuli

Table 2.8: *ANOVA Self-Report Results for "booster trials" during Generalization Recall Phase*

	df Num	df Dem	F	Sig.	Partial Eta Squared
Orientation	1	88	19.119	<.001	.178
Group	1	88	0.328	.568	.004
Orientation*Group	1	88	3.515	.064	.038

Overall Generalization Recall Phase

Table 2.9: ANOVA Self-Report Results for during Generalization Recall Phase

	df Num	df Dem	F	Sig.	Partial Eta Squared
Orientation	2.88	253.03	0.523	.659	.006
Group	1	88	5.719	.019	.061
Orientation*Group	2.88	253.03	0.590	.615	.007

Note. Greenhouse-Geisser Correction.

Generalization Recall Phase: Time Effects

Table 2.10: ANOVA Self-Report Results by Orientation, Time, and Group during Generalization Recall Phase

	df Num	df Dem	F	Sig.	Partial Eta Squared
Orientation	2.93	222.88	0.420	.734	.005
Group	1	76	6.180	.015	.075
Orientation*Group	2.93	222.88	1.403	.243	.018
Time	2.11	160.01	26.259	<.001	.257
Time*Group	2.11	160.01	3.742	.024	.047
Orientation*Time	7.95	604.20	1.472	.164	.019
Orientation*Time*Group	7.95	604.20	0.716	.676	.009

Note. Greenhouse-Geisser Correction.

2.5 Skin Conductance Response Data

2.5.1 Acquisition Phase

Descriptive Statistics

Table 2.11: Statistics of SCR by Group during Acquisition Phase

Stimuli	Visual Group		Imagery Group	
	M	*SD*	*M*	*SD*
CS+	0.3	0.2	0.37	0.3
CS-	0.28	0.2	0.36	0.24
CS+ First	0.37	0.2	0.48	0.3
CS+ Second	0.25	0.2	0.29	0.3
CS- First	0.38	0.2	0.44	0.3
CS- Second	0.21	0.2	0.3	0.3

Note. Larger scores equate to a stronger negative rating after stimuli was viewed. CS+ = conditioned stimulus paired with shock; CS- = conditioned stimulus not paired with shock.

2.5.1 ANOVA Results

Table 2.12: *ANOVA of SCR for CS Type by Group during Acquisition Phase*

	df Num	df Dem	F	Sig.	Partial Eta Squared
CS Type	1	91	1.829	.180	.020
Group	1	91	2.104	.150	.023
CS Type*Group	1	91	0.337	.563	.004

Table 2.13: ANOVA SCR by CS Type, Time, and Group during Acquisition Phase

	df Num	df Dem	F	Sig.	Partial Eta Squared
CS Type	1	91	1.874	.174	.020
Group	1	91	2.149	.146	.023
CS Type*Group	1	91	0.128	.721	.001
Time	1	91	134.634	<.001	.597
Time*Group	1	91	0.675	.413	.007
CS Type*Time	1	91	0.006	.941	<.001
Type*Time*Group	1	91	6.768	.011	.069

2.5.2 Generalization Phase

Descriptive Statistics for Generalization Phase

Table 2.14: Statistics of SCR by Group during Generalization Phase

Stimuli	Visual Group		Imagery Group	
	M	*SD*	*M*	*SD*
CS+	0.19	0.2	0.17	0.2
CS-	0.14	0.2	0.12	0.2
GCS+/-10	0.15	0.2	0.15	0.2
GCS+/-20	0.16	0.2	0.15	0.2
GCS+/-30	0.19	0.2	0.15	0.2
B+	0.17	0.2	0.35	0.3
B-	0.18	0.2	0.35	0.3

Note. After controlling for orienting effects. Larger scores equate to a stronger negative rating after stimuli was viewed. CS+ = conditioned stimulus paired with shock; CS- = conditioned stimulus not paired with shock; GCS+/-10 = generalized conditioned stimulus 10-degrees from CS+; GCS+/-20 = generalized conditioned stimulus 20-degrees from CS+; GCS+/-30 = generalized conditioned stimulus 30-degrees from CS+; B+ = CS+ booster trials; B- = CS- booster trials.

2.5.2 ANOVA Results

Boosters

Table 2.15: ANOVA SCR Results by Booster Type, Time, and Group during Generalization Phase

	df	df	F	Sig.	Partial Eta Squared
Type	1	91	0.448	.505	.005
Group	1	91	9.297	.003	.093
Type*Group	1	91	0.015	.901	<.001
Time	2.53	229.76	5.171	.003	.054
Time*Group	2.53	229.76	0.675	.543	.007
Type*Time	2.87	261.50	0.202	.888	.002
Type*Time*Group	2.87	261.50	0.994	.394	.011

Note. Greenhouse-Geisser correction.

Overall Boosters

Table 2.16: ANOVA SCR for Boosters Trials during Generalization Phase

	df Num	df Dem	F	Sig.	Partial Eta Squared
B Type	1	91	0.128	.721	.001
Group	1	91	9.114	.003	.091
B Type*Group	1	91	0.109	.741	.001

Note. Greenhouse-Geisser Correction.

Generalization Phase Time Effects

Table 2.17: ANOVA SCR Results by Orientation, Time, and Group during Generalization Phase

	df	df	F	Sig.	Partial Eta Squared
Orientation	3.44	312.98	1.217	.304	.013
Group	1	91	0.046	.831	.001
Orientation*Group	3.44	312.98	0.314	.841	.003
Time	2.74	249.03	33.448	<.001	.269
Time*Group	2.74	249.03	1.114	.341	.012
Orientation*Time	8.47	771.15	3.288	<.001	.035
Orientation*Time*Group	8.47	771.15	0.831	.581	.009

Note. Greenhouse-Geisser correction.

Generalization Phase (First Block)

Table 2.18: ANOVA SCR for First Block of Generalization Phase

	df Num	df Dem	F	Sig.	Partial Eta Squared
Orientation	3.28	298.53	3.587	.012	.038
Group	1	91	0.079	.780	.001
Orientation*Group	3.28	298.53	0.169	.930	.002

Note. Greenhouse-Geisser Correction.

Figure 1: SCR of the first block of the Generalization Phase.

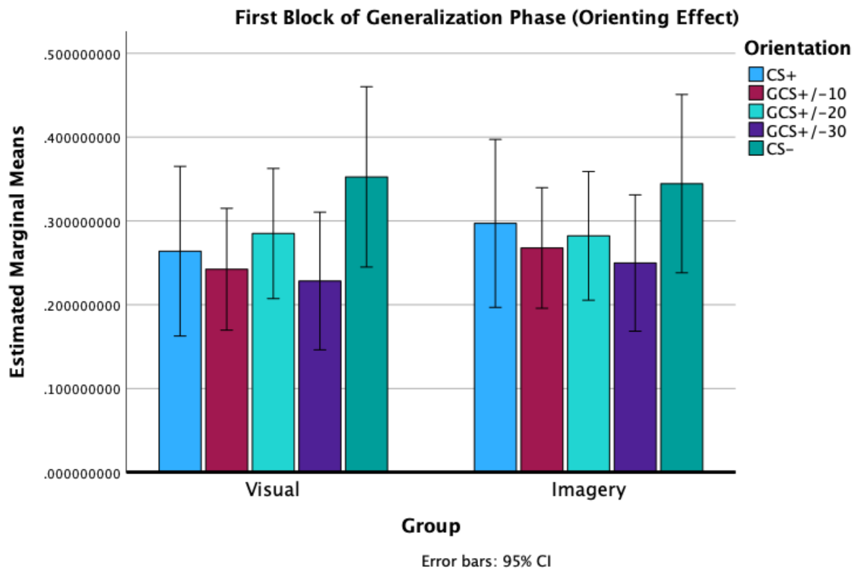
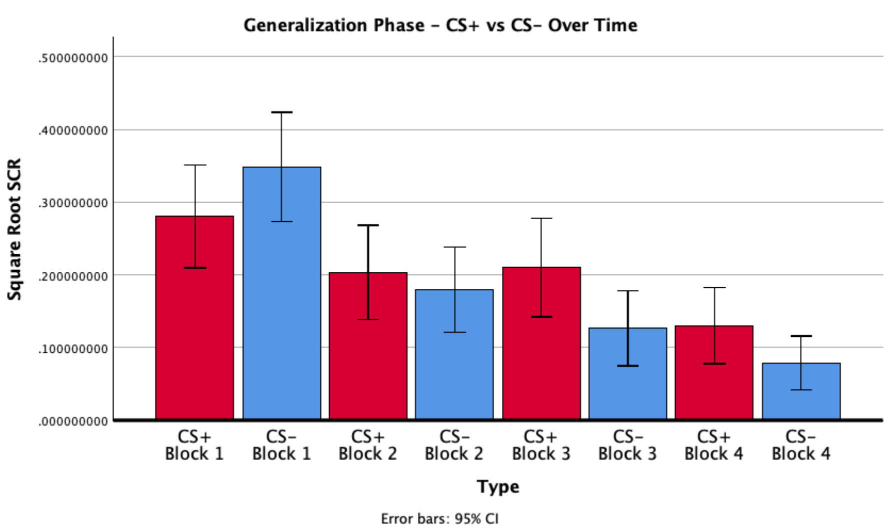


Figure 2: SCR of the Generalization Phase for CS+ and CS-.



Generalization Phase ANOVA (First Block Removed)

Table 2.19: ANOVA SCR for Generalization Phase

	df Num	df Dem	F	Sig.	Partial Eta Squared
Orientation	3.50	318.89	2.809	.032	.030
Group	1	91	0.192	.662	.002
Orientation*Group	3.50	318.89	0.347	.822	.004

Note. Greenhouse-Geisser Correction.

2.5.3 Generalization Recall Phase

Descriptive Statistics

Table 2.20: Statistics of SCR by Group during Generalization Recall Phase

Stimuli	Visual Group		Imagery Group	
	M	*SD*	*M*	*SD*
CS+	0.22	0.2	0.2	0.2
CS-	0.2	0.2	0.25	0.2
GCS+/-10	0.22	0.2	0.21	0.2
GCS+/-20	0.25	0.2	0.23	0.2
GCS+/-30	0.23	0.2	0.22	0.2
B+	0.23	0.2	0.48	0.4
B-	0.21	0.2	0.42	0.4

Note. Larger scores equate to a stronger negative rating after stimuli was viewed. CS+ = conditioned stimulus paired with shock; CS- = conditioned stimulus not paired with shock; GCS+/-10 = generalized conditioned stimulus 10-degrees from CS+; GCS+/-20 = generalized conditioned stimulus 20-degrees from CS+; GCS+/-30 = generalized conditioned stimulus 30-degrees from CS+; B+ = CS+ booster trials; B- = CS- booster trials.

2.5.3 ANOVA Results

Boosters

Table 2.21: ANOVA SCR Results by Booster Type, Time, and Group during Generalization Recall Phase

	df	df	F	Sig.	Partial Eta Squared
Type	1	78	8.147	.006	.095
Group	1	78	12.940	<.001	.142
Type*Group	1	78	2.370	.128	.029
Time	2.19	170.89	60.493	<.001	.437
Time*Group	2.19	170.89	0.739	.491	.009
Type*Time	2.49	193.84	1.784	.161	.022
Type*Time*Group	2.49	193.84	1.368	.256	.017

Note. Greenhouse-Geisser correction.

Overall Boosters

Table 2.22: ANOVA SCR for Boosters Trials during Generalization Recall Phase

	df Num	df Dem	F	Sig.	Partial Eta Squared
B Type	1	78	8.147	.006	.095
Group	1	78	12.940	<.001	.142
B Type*Group	1	78	2.370	.128	.029

Generalization Recall Phase by Time

Table 2.23: ANOVA SCR Results by Orientation, Time, and Group during Generalization Recall Phase

	df	df	F	Sig.	Partial Eta Squared
Orientation	3.22	251.11	1.122	.343	.014
Group	1	78	0.002	.968	<.001
Orientation*Group	3.22	251.11	1.633	.179	.021
Time	1.99	155.23	51.659	<.001	.398
Time*Group	1.99	155.23	1.815	.167	.023
Orientation*Time	8.64	673.71	1.777	.072	.022
Orientation*Time*Group	8.64	673.71	2.135	.027	.027

Note. Greenhouse-Geisser correction.

Generalization Recall Phase ANOVA

Table 2.24: ANOVA SCR for Generalization Recall Phase

	df Num	df Dem	F	Sig.	Partial Eta Squared
Orientation	3.22	251.11	1.122	.343	.014
Group	1	78	0.002	.968	<.001
Orientation*Group	3.22	251.11	1.633	.179	.021

Note. Greenhouse-Geisser Correction.

2.5.3 Pairwise Comparison Results

Here are the SCR extinction results broken out by group in the Generalization Recall phase not included in the manuscript.

Table 2.25: Visual Group Paired Samples Test for Generalization Recall Phase

First vs. Second Half Comparison	df	t	Sig.	d
CS+	36	4.192	<.001	0.689
CS-	36	4.824	<.001	0.793
GCS+/-10	36	3.729	<.001	0.613
GCS+/-20	36	6.067	<.001	0.997
GCS+/-30	36	4.691	<.001	0.771

Table 2.26: Imagery Group Paired Samples Test for Generalization Recall Phase

First vs. Second Half Comparison	df	t	Sig.	d
CS+	42	-0.55	.582	0.085
CS-	42	3.948	<.001	0.602
GCS+/-10	42	3.757	<.001	0.573
GCS+/-20	42	4.935	<.001	0.753
GCS+/-30	42	4.58	<.001	0.698