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The Generalization of Fear Condition Between Viewed and Imagined Percepts

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THE GENERALIZATION OF FEAR CONDITION BETWEEN VIEWED AND IMAGINED PERCEPTS

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Abstract

Mental images can provoke intense emotional states (Holmes & Matthews, 2010). Imagery and perception have common neural and physiological mechanisms, including activation of the early visual areas (Albers et al., 2013). We tested the prediction that individuals can acquire fear to imagined percepts and if this fear transfers to viewing percepts, using fMRI and self-reported measures to determine participants' fear. The participants completed a task in which they viewed and imagined two stimuli, and were fear conditioned when imagining the CS+. Participants are only told that mild electrical stimulation will be paired with one of the stimuli, but not which stimulus, viewed or imagined. Participants completed 6 runs of each task after completing 6 runs of a habituation form of each task. Behaviorally, participants report greater fear when imagining the CS+ than imagining the CS-. When acquiring fear to an imagined stimulus, we found significant activation in the right insula. These findings are consistent with previous literature indicating that this region is involved in processes related to emotional memory, autonomic arousal, and emotion-related motivation. Behaviorally, participants also report greater fear when viewing the CS+ than when viewing the CS-, though neither is ever paired with shock. When determining if fear is generalized from an imagined precept to a viewed one (i.e., CS+ view > CS- view), we found no significant activation. We can conclude that participants generalize the fear acquired when imagining the stimulus to viewing the stimulus. Finally, participants also show a similar level of self-reported fear to fear conditioning acquired to imagining a stimulus as to when fear is acquired to viewing a stimulus. We found insular cortex and precentral gyrus activation when investigating the similarities between these processes. These results indicate: that humans can fear condition to imagined percepts, which involves activation of anterior insula; that this fear conditioning generalizes to instances of viewing the conditioned percept; and that differential conditioning to both imagined and viewed percepts produced a similar magnitude of subjective fear along with activation of the right anterior insula.

Introduction

"Our fear of monsters in the night probably has its origins far back in the evolution of our primate ancestors, whose tribes were pruned by horrors whose shadows continue to elicit our monkey screams in dark theaters" (Shepard & Midgley, 1996). This quote brings to light an uncommonly thought of concern: mental images can provoke intense emotional states. For example, a child imagining a monster under his bed experiences fear, even though he is at no risk of harm. In this case, the child has an emotional reaction to situations that are not tangible and experienced, rather situations that are constructed in the mind. This thesis seeks to further our understanding of how the acquisition and generation of fear produced in the mind's eye (i.e., using mental imagery) relates to, and differs from, fear acquired and generated from external stimuli. The overarching hypothesis is that the acquisition and production of fear through the imagination is facilitated by a different neural system than fear that is produced through visual percepts, but that both pathways lead to the activation of core affect regions involving the amygdala and anterior insula.

The following introductory sections will provide a detailed description of previous research from which the overall hypothesis is derived. I will discuss the relationship between fear and anxiety in psychopathology and emotions, the similarities between perception and mental imagery, emotion and the neural mechanisms involved in fear conditioning learning in emotional mental imagery. These topics will converge on the hypotheses of this study followed by the methods of the experiment along with the results and their implications.

Fear, Anxiety, and Psychopathology

Psychopathology, such as anxiety and post-traumatic stress disorder (PTSD), are rooted in fear and imagery (Arntz, Tiesema, & Kindt, 2007; Shin & Liberzon, 2010). Anxiety can be

seen in as much as five percent of the general population (Muse, McManus, Hackmann, Williams, & Williams, 2010) and 96 percent of postgraduate students (Erfanmanesh, Abrizah, & Karim, 2017). Levels of anxiety, as well as depression, have significantly increased between 1990 and 2010 (Baxter et al., 2014). This study will further the knowledge and understanding of fear acquired to an imagined percept, thereby allowing us to better understand these prominent mental health issues.

Imagery is a common component of various symptoms associated with PTSD and other anxiety disorders (Muse et al., 2010). In such cases, imagery usually involves the recall of aversive incidents previously experienced during childhood or when the disorder began (Hackmann, Clark, & McManus, 2000; Muse et al., 2010). This imagery can involve many sensory modalities, (Kamitani & Tong, 2005) however, visual elements are most common (Hackmann et al., 2000). Imagery is a common feature of PTSD, as individuals often re-experience the traumatic situation. During imagery in PTSD, individuals experience the emotions that occurred during the original traumatic event, which can be triggered either intentionally or unintentionally (Hackmann & Holmes, 2004). In anxiety, the imagery experienced is often spontaneous and includes aversive memories that have been previously experienced or learned (Hackmann et al., 2000; Hackmann & Holmes, 2004). These images are believable to the individual, making the imagery difficult to appraise (Hackmann & Holmes, 2004; Muse et al., 2010). While we don't have a deep understanding of fear acquired to an imagined stimulus, this research shows that this fear can have an influential impact on an individual.

There are multiple explanations concerning the ability of imagery to evoke emotions. The first possible explanation involves the use of similar brain systems for both imagery and

perception. The regions that are activated when perceiving a stimulus are also activated when imagining the same stimulus (E. A. Holmes & Mathews, 2010). This is also true for imagery of emotional stimuli. When participants imagine a face expressing a particular emotion, the same regions become activated as when participants view the same face stimulus (E. A. Holmes & Mathews, 2010; Kim et al., 2007). Imagery may also be linked to emotions through the robust connections between emotional regions such as the amygdala and medial temporal lobe (MTL) structures such as the hippocampus. For example, autobiographical memory involving imagery is a key factor in remembering (Brewer, 1996; E. A. Holmes & Mathews, 2010) and is influenced by the emotional intensity of the stimulus or situation (Talarico, LaBar, & Rubin, 2004).

Imagery and Perception

Mental images are depictions of stimuli constructed in the mind that cause sensory changes in the individual. They allow us to partake in mental events that aid in processes such as remembering, planning, navigating, and decision making (Pearson, Naselaris, Holmes, & Kosslyn, 2015). Within the brain, mental images undergo processes similar to that of perception. Partaking in mental visual imagery processes interferes with visual perception (Horowitz, 1969). This is because mental images retain the sensory characteristics and neural processes of perceived stimuli, and utilize information of previously perceived stimuli to generate the image (Dadds et al., 1997; Kosslyn, 1988).

There are two main processes that are required to form mental images. The first is a long-term memory of the stimuli that will be imagined. The second is the process of generating an image. Generating the image uses information from the long-term memory in order to construct a short-term mental image (Farah, Hammond, Levine, & Calvanio, 1988). Even though mental imagery is formed from memories, the experience of a mental image can be perceived as a

present stimulus and cause reactions similar to viewing the image (E. Holmes & Hackmann, 2004).

Mental imagery and visual perception share some common underlying neural and physiological mechanisms. Both activate the early regions of the visual cortex (V1-V3) (Albers, Kok, Toni, Dijkerman, & de Lange, 2013), though the magnitude of activation is greater for viewing compared to imagining (Tootell et al., 1998). Mental imagery, generates only a low level of neural activity compared to perception of visual stimuli. This makes studying the neural basis of mental imagery difficult. Recent advances in the analysis of functional magnetic resonance imaging (fMRI) provides a tool for measuring one's mental imagery. Despite the low neural activity, V1-V3 activation can accurately depict the orientation gratings of imagined stimuli (Albers et al., 2013; Kamitani & Tong, 2005). Multivoxel Pattern Analysis (MVPA) is a machine learning technique that can be used to analyze the neural patterns in visual areas V1 and V2 during perception. This analysis can, in turn, verify the stimuli participants imagine during each trial. This not only allows for verification of the mental image produced by participants during each trial, but also further supports the similar relationship of mental imagery and perception (Albers et al., 2013; Cichy, Heinzle, & Haynes, 2011; Kamitani & Tong, 2005; Pearson et al., 2015).

Another similarity in neural responses between imagined and viewed stimuli is pupil restriction. When imagining a stimulus, the amount of pupil constriction is similar to what is found based on the brightness of the same viewed visual stimuli (Laeng & Sulutvedt, 2014). These similarities indicate a strong connection between mental imagery and perception (Albers et al., 2013; Dadds et al., 1997; E. A. Holmes & Mathews, 2010; Kosslyn, 1988). The similar visual cortex activation, as well as an individual's ability to mentally produce an image may

influence the individual's task performance (Logie, Pernet, Buonocore, & Della Sala, 2011; Pearson et al., 2015). Though there are clear similarities in the neural mechanisms of imagery and perception, their levels and patterns activation are not uniform (Ganis, Thompson, & Kosslyn, 2004). These similarities suggest a relationship between mental imagery and perception, which we will investigate further in the proposed study.

Fear and Emotion

A consensus definition of emotion remains lacking in the literature. This study will follow an operational definition derived from James Gross, indicating that emotions are a psychological state consisting of behavioral expression as well as physiological response. It will also follow the guidance of James Gross' modal model (Figure 1). According to this view, emotions are connected to emotion-eliciting situations, which can either be reflected in the external environment or be internally generated (Gross & Feldman Barrett, 2011). Specifically, following the introductory example of a child becoming scared of a monster under his/her bed, we argue that situations can be internally generated. Therefore, emotions can be linked to mental imagery.

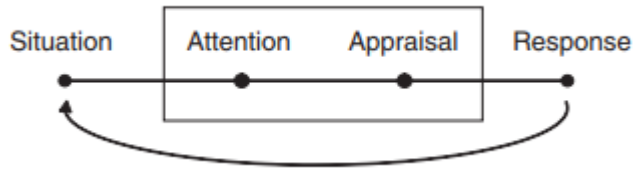


Figure 1. Gross' modal model of emotion (Gross & Feldman Barrett, 2011).

Pavlovian fear conditioning is widely used to provoke emotional states (Cheng, Knight, Smith, & Helmstetter, 2006; Dunsmoor, Bandettini, & Knight, 2008; Knight et al., 2005). This process involves a neutral conditioned stimulus (CS), such as a tone or image, paired with an unconditioned stimulus (US), such as mild electrical stimulation or an aversive noise, which is followed by an unconditioned response (UR), such as fear, pain, or autonomic arousal. This pairing results in the conditioned stimulus that was paired with the US (CS+) producing a conditioned response (CR) that includes factors similar to the UR, most notable a feeling of fear or threat reactivity along with autonomic reactivity. Most often, experiments employ differential fear conditioning, which along with the CS+, includes a conditioned stimulus that is never paired with the US (CS-).

Neural Activation and Fear Conditioning

Skin Conductance Response (SCR) is widely used in many types of studies for its ability to measure psychological states through sweat gland activity. It has been shown that SCR is a reliable variable used to measure autonomic emotional expressions(Lang, Bradley, & Cuthbert, 1998). Fearful situations, a combination of stimulating arousal and unpleasant affective valence, have been shown to increase SCRs. When presented with happy, sad, peaceful, and fearful music, participants produced the largest SCR to fearful pieces (Khalfa et al., 2002). SCR has also been used in classical conditioning. During training, participants show a larger SCR to CS+ trials than CS- trials, signifying greater emotion to the CS+ stimulus than the CS- stimulus (Dunsmoor, Bandettini, & Knight, 2007; Knight et al., 2005). The occurrence of a CS+, the increase in amygdala activity, and SCR are related (Cheng et al., 2006; Cheng et al., 2003; Knight et al., 2005).

It has been shown that the expectation of a US during the presentation of a CS+ modulates brain activity in humans (Dunsmoor et al., 2008). The amygdala is thought to moderate memories and successfully form a CS-US association in Pavolvian fear conditioning (Cheng et al., 2006; Dunsmoor et al., 2007; Knight et al., 2005; LeDoux, 2000; Maren & Fanselow, 1996). The amygdala, however, does not require conscious awareness of a stimulus for this fear association to be made (Morris, Öhman, & Dolan, 1999). The colliculo-pulvinar-amygdala pathway, involved in autonomic responses and reflexive reactions, allows relevant qualities of an individual's environment to be identified regardless of awareness (Büchel & Dolan, 2000; Cheng, Knight, Smith, Stein, & Helmstetter, 2003; Morris et al., 1999). The amygdala also moderates the production of an individual's conditioned SCR. This means that during the occurrence of a CS+, the increase in amygdala activity and SCR are related (Cheng et al., 2006; Cheng et al., 2003; Knight et al., 2005).

Additional cortical regions appear to be involved in a conditioned response. The insula, as well as the dorsolateral prefrontal cortex, generate a larger response during uncertain or partial conditioning trials (Critchley, Mathias, & Dolan, 2001; Dunsmoor et al., 2007; Ploghaus, Becerra, Borras, & Borsook, 2003). This is also true of emotionally salient stimuli (Adolphs, 2002; Wicker et al., 2003) in both younger and older adults (Lee et al., 2018).The posterior insula aids in modulating the emotions caused by an uncertainty of receiving a painful stimulus (Sawamoto et al., 2000).

The insula is responsive to processes involved in fear memory (Dunsmoor et al., 2007; Merz et al., 2010) and monitoring emotions (Britton et al., 2006). Insula activity correlates with emotional stimuli, as well as uncertainty. When conditioning is not reinforced on 100 percent of

the trials and is therefore less predictable, greater activity is shown in the insula (Dunsmoor et al., 2007).

Fear and Imagery

Though there has been no research on how fear conditioning, and the generalization of acquired fear between perceiving and imagining, one study has examined the role of imagery in the acquisition of emotional conditioning. Lewis et al. (2013) sought to determine if mental imagery could be associated with emotion-evoking photographs. During the learning phase, participants were to associate a letter cue with the associated pattern. When the letter was presented, participants would imagine the associated pattern, then view a pleasant or aversive photograph (Figure 2). Participants then completed the test phase in which the pattern was presented, followed by a pleasant or aversive photograph. When the image was displayed, the participants were to indicate whether the stimulus was pleasant or aversive (Figure 3).

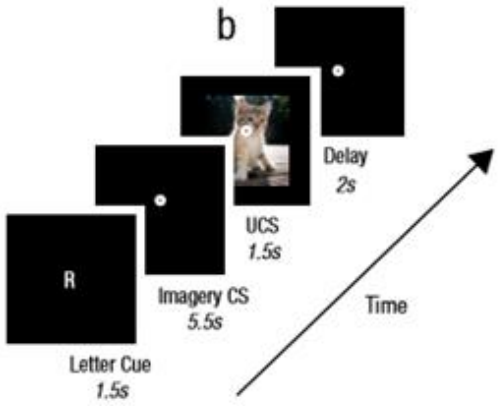


Figure 2. Learning phase. Participants imagine the pattern associated with the Letter cue then view an emotional UCS (Lewis, O'Reilly, Khuu, & Pearson, 2013).

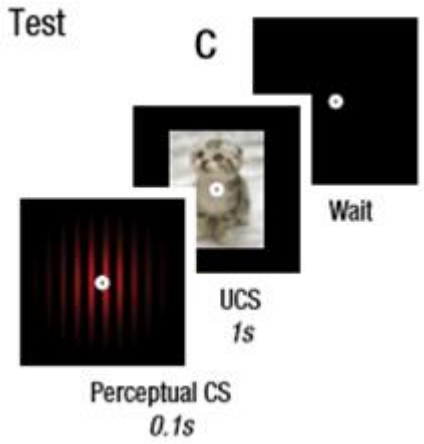


Figure 3. Test phase. Participants must indicate whether a UCS is aversive or pleasant (Lewis et al., 2013).

This study used reaction times to determine if the emotional content was properly associated with the pattern presented. If reaction times were quicker, then participants accurately associated the pattern with the emotion of the image during the learning phase. When collapsing across emotions, they found quicker reaction times based on emotional congruence, meaning reaction times were faster when the pattern's emotion matched the image's emotional content. Therefore, they concluded that associative learning connected the emotional content of images and mentally generated stimuli (Lewis et al., 2013).

This study, however, contains limitations which the study proposed in this thesis will address. First, there was no imagining during the test phase. This leaves a gap in which generalization must be assumed from learning to test phase, rather than verified and tested. Also, the associative learning and emotional responses relied on response time. While the results produced an effect, and showed this associative learning occurred, we are unable to determine the nature of the emotional response. As the study was entirely behavioral, it cannot speak directly to the underlying neural processes responsible for associative learning involving imagery (Lewis et al., 2013).

Study Purpose: Integrating the neural and subjective bases of fear learning

Little is known about how the differences between imagery and perception are important for emotion, the neural processes that are involved in emotional mental imagery, and how the range of complexity in emotional images is represented in the mind. The purpose of this study is threefold: 1) To determine if we acquire fear to imagined percepts, and the neural underpinnings of this process; 2) To determine if fear acquired to imagined percepts generalizes to matching visual percepts, and the neural underpinnings of this process; 3) To determine if fear acquired to imagined CSs is distinct from fear acquired to viewed CSs, and the neural underpinnings of this

process. While it has been shown that mental images can be used as an emotion evoking stimuli and this association can generalize from imagined to perceived stimuli (Lewis et al., 2013; Pearson et al., 2015), these inferences rely solely on faster reactions times to emotionally congruent stimulus presentations. The study by Lewis (2013) did not involve self-reported measures of affect, physiological markers of emotional learning such as SCR, or have the neural mechanisms of these processes been observed. Moreover, the mental processes that occur through fear learning in mental imagery and how this process is similar to that of perception. In the current study, we will compare participants' capacity to generate a fear response to both viewed and imagined stimuli. Identifying and quantifying the transfer of fear from a imagined to viewed stimuli, provides new knowledge regarding the processes and mechanisms of fear learning in the brain. The next section provides a detailed exposition of our hypothesis and their rationale.

Hypotheses

There are three main purposes of this study. First, to determine if we acquire fear to imagined percepts (hypothesis 1). For this point, we expect greater levels of activation in the CS+ condition compared to the CS- condition. Second, to determine if fear acquired to imagined percepts generalizes to matching visual percepts (hypothesis 2). Here we expect participants to generalize this fear acquired in hypothesis 1 from imagined to viewed stimuli. Third, to determine if fear acquired to imagined CSs has distinct neural signatures from fear acquired to viewed CSs (hypothesis 3). We expect similar magnitude of fear, as indicated by the self-report, but different neural mechanisms in this assessment. These hypotheses are addressed below.

Hypothesis 1

All analyses for hypothesis 1 use the CS+ imagine and CS- imagine conditions from the Imagery Acquisition phase. We expect participants to have a greater self-reported fear of the CS+ imagine condition than the CS- imagine condition. In fMRI scans, when the unconditioned stimulus is paired with the conditioned stimulus during the task, the amygdala produces a response for the CS+ but does not produce a response during CS- trials (Dunsmoor et al., 2007). Therefore, during Imagery Acquisition, greater amygdala activity is expected for the CS+ imagine than the CS- imagine. An increase of activity in the insula has also been found during differential fear conditioning tasks (Lee et al., 2018). Due to this, we also expect greater insula activity when presented with the CS+ imagine than the CS- imagine.

Hypothesis 2

All analyses for hypothesis 2 use the CS+ view and CS- view conditions from the Imagery Acquisition phase. We predict fear conditioning to an imagined stimulus will produce a generalized fear response such that viewing the imagined stimulus produces fear. Therefore, as

in hypothesis 1, we expect participants to have a greater self-reported fear of the CS+ view condition than the CS- view condition. Again, as in hypothesis 1, we expect the neuroimaging data to result in greater amygdala and insula activity when viewing the CS+ as compared to viewing the CS-.

Hypothesis 3

Hypothesis 3 analyses use both the Imagery Acquisition and Visual Acquisition phases. The self-reported data includes the CS+ imagine condition from the Imagery Acquisition phase and the CS+ view condition from the Visual Acquisition phase. Here we expect to find no significant difference between the CS+ imagine and the CS+ view conditions in the self-reported Likert style questionnaire, indicating that participants produce a subjective fear of similar magnitude when acquiring fear to an imagined and a viewed stimulus.

The first fMRI analyses use both the difference between CS+ imagine and CS- imagine conditions from the Imagery Acquisition phase, as well as the difference between the CS+ view and CS- view conditions from the Visual Acquisition phase. When investigating this interaction, we expect to find activation in both the amygdala and insula, such that the magnitude of activation in each region is larger when viewing than imagining. In the second set of fMRI analyses, we use the CS+ imagine condition from the Imagery Acquisition phase and the CS+ view condition from the Visual Acquisition phase. This contrast allows us to investigate the activation in regions associated with imagining versus viewing. Here we expect to find greater activation in the frontoparietal regions when imagining. When viewing, we expect greater activation in the visual cortex and the thalamus. When investigating the neural similarity between acquiring fear to an imagined stimulus and acquiring fear to a viewed stimulus, we

expect to find significant differential (CS+ > CS-) activation irrespective of acquisition type (viewing or imagining) in the anterior insula and amygdala.

Method

Participants

A power analysis using NeuroPowerTools, a sample size calculation tool for fMRI experiments based on statistical mapping, was conducted to determine the ideal sample size for this study (Durnez et al., 2016). Data from a previous similar fMRI study was used as pilot data in this analysis. To achieve a statistical power of 0.8 with an alpha of 0.05, this study will assemble a sample size of about 30 participants. This study includes 33 healthy adults between the ages of 18-45. These participants had no neurological disorders, did not self-report as having a clinically diagnosed mental illness, nor were they on any pharmacological intervention for any mental illnesses. Participants were also required to have no metal in their body due to MRI safety. Two participants were not included in the subsequent analyses due to technical equipment errors. All participants gave written informed consent and the study was approved by LSU's institutional review board.

Participants also completed a demographic form, the Vividness of Visual Imagery Questionnaire (VVIQ), the State-Trait Anxiety Inventory (STAI), and the Attentional Control Scale for potential secondary post hoc analyses. For example, the activation of an individual's early visual cortex while imagining correlates to their VVIQ score (Dijkstra, Bosch, & van Gerven, 2017). Individuals with high anxiety have shown increased activity in the amygdala when confronted with aversive stimuli (Indovina, Robbins, Núñez-Elizalde, Dunn, & Bishop, 2011). Having these measures will allow us to look at individual differences, yet such analysis are beyond the scope of the current study.

Task Design

To determine whether fear can be acquired for imagined stimuli, and the generalizability of this fear to viewed stimuli, four Gabor patches were adopted as conditioned stimuli (CSs). The schedule of stimulus presentation and data collection was controlled by PsychToolbox in Matlab R2015b (MathWorks Corp., Natrick, MA, USA). Mild electrical shock was used as the unconditioned stimulus (US) and was delivered to the index and middle finger of the non-dominant hand via a shock stimulator MP-150 BIOPAC system (BIOPAC systems, Goleta, CA). The intensity of the electric shock was set at a level that was "uncomfortable but not painful", as determined by each participant individually, consistent with previous research (Cheng et al., 2006; Cheng et al., 2003; Knight et al., 2005; LaBar et al.; Tabbert et al.). Trials that included shocks were excluded in subsequent analyses.

This study involved two independent conditioning phases, each using a unique set of stimuli; the Imagery Acquisition phase consisted of left and vertical Gabor patches while the Visual Acquisition phase included horizontal and right patches. Along with the patches presented, the major difference between these sets was the stimuli associated with the mild electrical stimulation. In the Imagery Acquisition phase, the mild electrical stimulation was presented during 50% of trials in which the participant imagined either the left or vertical patch, while in the Visual Acquisition phase, the mild electrical stimulation was presented during 50% of trials in which the participant viewed either the horizontal or right patch (Figure 4). This reinforcement rate allows a measurement of CS+ evoked hemodynamic responses without the effect of the US confounding the data. This approach was successful at eliciting a conditioned response of non-reinforced CS+ trials compared to CS- trials. The order in which the sets were presented was counterbalanced between subjects.

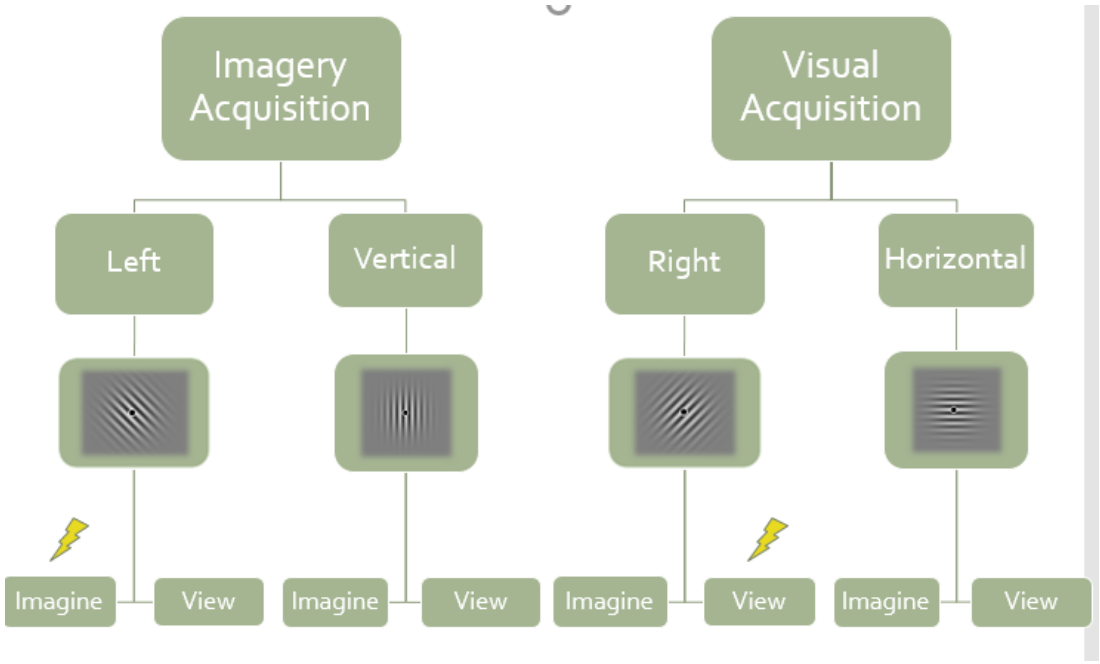


Figure 4. Layout of sets, Gabor patches, and mild electrical stimulation. Every participant both views and imagines all four patches but are only shocked to one imagine patch during Imagery Acquisition and one view patch during Visual Acquisition.

Prior to each conditioning phase, participants completed a habituation task consisting of one run, before each phase. One run consisted of 12 trials, or 12 Gabor patches. The presentation of patches is discussed in more detail below. During this habituation task, participants were instructed to view and imagine each patch to be presented in the associated set. The conditioning task consisted of four runs of each set in which during the Imagery Acquisition, either the imagined left or imagined vertical patch was paired with the electric shock, and in the Visual Acquisition, the perceived right or perceived horizontal patch was paired with the electric shock. The patch chosen as a conditioned stimulus with shock was counterbalanced across participants. Each trial in the conditioning session began with the onset of a white fixation dot against a gray background for 2 seconds. Participants were then presented with a black fixation dot and an auditory cue to direct them to either view or imagine the patch, lasting 1.5 seconds. The black fixation dot continued to appear for 4 additional seconds while the participant either attended to

the presentation of a patch or imagined the patch dictated by the auditory cue. Participants were instructed to relax and stop imagining when the black dot disappears. If the trial was assigned to the CS+ with shock condition, a shock was delivered for 5ms at the end of the 4 second presentation, followed by a white fixation dot for 10 seconds (Figure 5). During the CS- and CS+ without shock trials, there was no shock and the 4 second interval was followed by a white fixation dot for 10 seconds. Participants were informed that one of the patches were to be paired with shock but they were not told which patch was selected.

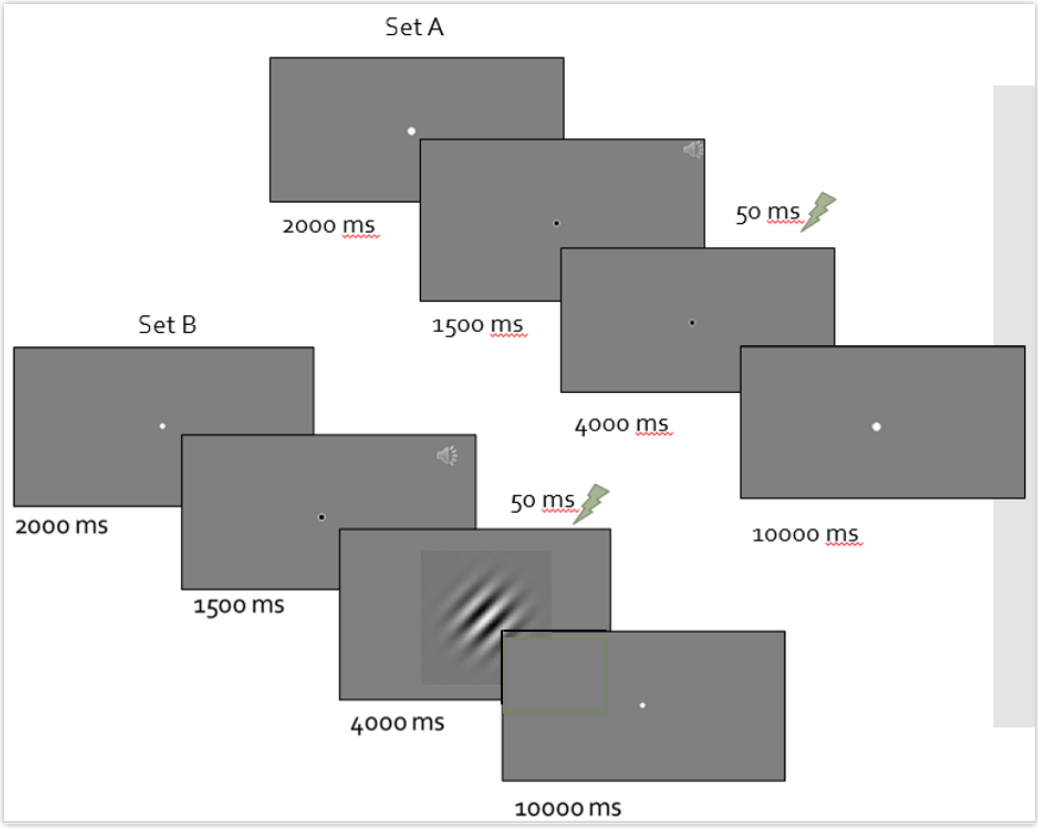


Figure 5. Trial structure for the fear conditioning task. A total of 12 trials are presented in semi-random order. Imagery-Acquisition: Participants are shocked when imagining a stimulus. Visual Acquisition: Participants are shocked when viewing a stimulus. *Stimulus enlarged to show patch

A total of 12 trials were presented in semi-random order during both the habituation and the task. In the Imagery Acquisition, the following conditions were presented: 2 CS+ imagine with shock, 2 CS+ imagine without shock, 4 CS- imagine, 2 CS+ view, and 2 CS- view. A CS- imagine was always the first trial, followed by a CS+ imagine with shock trial, while the other CS+ imagine with shock trial was presented randomly within the second half of the task, and a CS- imagine trial was always presented last. In the Visual Acquisition, the following conditions were presented: 2 CS+ view with shock, 2 CS+ view without shock, 4 CS- view, 2 CS+ imagine, and 2 CS- imagine. A CS- view trial was always presented first, followed by a CS+ view with shock trial, while the other CS+ view with shock was presented randomly within the second half of the trials, and a CS- view trial was always presented last.

Before going into the scanner, participants completed all consent, forms, and questionnaires. They were also given written instructions of the task to be sure they were aware of the task. Participants were also shown a slide show about the MRI, MRI safety, and an overview of what would happen in the scanner. When participants went into the scanner, first an anatomical scan (T1) was run. Participants then completed the shock threshold task to determine what level the electrical stimulation should be for the remainder of the study. For one set, the habituation task was presented for 6 runs with no shocks given, then the conditioning task was presented for 6 runs with shocks given. The Likert style questionnaire regarding the set was then completed. Participants then repeated the habituation task, conditioning task, and Likert style questionnaire for the second set.

Measures

Fear contingent responding is assessed using a Likert style questionnaire, SCR, and functional Magnetic Resonance Imaging (fMRI). After each set, the participants completed a

Likert scale questionnaire (1-7, higher value indicating greater fear) in which they reported the vividness of their mental imagery for the respective imagine patches, how hard they tried to form mental images for the respective imagine patches, and how much they feared the shock on the respective view and imagine patches. A copy of the questionnaire is included in Appendix 1.

Physiological Recordings: Individual SCRs were acquired to confirm the success of the emotional arousal manipulation by electrodes placed on the ring and pinky finger of the non-dominant hand. All physiological data were recorded at 1000 Hz sampling rates through the MP-150 system (BIOPAC System, Goleta, CA, USA), connected to a grounded RF filter, leads, and electrodes.

Due to the time consuming nature of fMRI and SCR analyses, SCR has not yet been analyzed for this study. This psychophysiological data will be analyzed in the future for publications, but was disregarded here as it requires additional time and attention for accurate cleaning and analyses.

Image Acquisition and Analysis. Brain images were collected using a 3 Tesla GE Discovery MR750w system with a 32-channel matrix head coil at Pennington Biomedical Research Center in Baton Rouge, Louisiana. Functional images were acquired using a gradient-echo, echo-planar, T2-weighted pulse sequence (TR= 2000 ms, TE= 25 ms, flip angle = 90°, 64 x 64 matrix, phase encoding direction posterior to anterior). Thirty-six slices covering the entire brain were acquired with an in-plane voxel resolution of 3.5 x 3.5 and a slice thickness of 3.5 mm with no gap. Slices were acquired in interleaved ascending order, and 112 functional volumes were acquired in each run, not including 3 discarded dummy volumes to account for T1 equilibrium effects.

A T1-weighted high-resolution image was acquired using a three-dimensional magnetization-prepared rapid acquisition gradient (MPRAGE) sequence (TR= 2000 ms, TE= 3.8 ms, flip angle= 8°, 176 x 256 matrix, phase encoding direction posterior to anterior). 256 slices covering the entire brain were acquired in interleaved ascending order with a voxel resolution of 1 x 1 x 1 mm.

The following fMRI analyses were conducted using FEAT (FMRI Expert Analysis Tool) Version 5.0, part of FSL [FMRIB's Software Library] (Smith et al., 2004). The following preprocessing steps were applied; motion correction using MCFLIRT (Jenkinson, Bannister, Brady, & Smith, 2002); slice-timing correction using Fourier-space time-series phase-shifting; non-brain removal using BET (Smith, 2002); spatial smoothing using a Gaussian kernel of FWHM 7mm; grand-mean intensity normalization of the entire 4D dataset by a single multiplicative factor; registration to high resolution structural and standard Montreal Neurological Institute (MNI) 2-mm brain using FLIRT (Jenkinson et al., 2002).

Results

There were three hypotheses tested with this study. The first hypothesis investigates whether participants can acquire fear to an imagined stimulus. The second hypothesis determines whether participants generalize this fear to the respective viewed stimulus. Lastly, the third hypothesis states that fear acquired to imagined and viewed stimuli will be similar in magnitude in core affect regions but capitulated by different neural mechanisms. The data from the habituation runs and data from the imagine conditions in the Visual Acquisition phase are not presented here as they are not relevant to the hypotheses that are currently being tested. Each hypothesis will be addressed for each measure collected below.

Likert Style Questionnaire

Self-Reported Vividness and Effort. At the end of each phase we asked participants to rate their vividness and effort used to create a mental image of each imagined stimulus. There was no significant difference in the self-reported vividness levels of the CS+ imagine (M=5.03, SD=1.56) and CS- imagine (M=5.00, SD=1.41) conditions in the Imagery Acquisition set, $t(30)= 0.11$, $p=0.91$. There was also no significant difference in the self-reported vividness levels of the CS+ imagine (M=4.93, SD=1.53) and CS- imagine (M=5.03, SD=1.56) conditions in the Visual Acquisition set, $t(30)= 0.47$, $p=0.64$. When looking at the amount of effort put towards generating a mental image, we also find no significant difference in the amount of effort used to generate a mental image to the CS+ imagine (M=5.17, SD=1.56) and CS- imagine (M=4.77, SD=1.55) conditions in the Imagery Acquisition phase, $t(30)=1.75$, $p=0.09$. Again, we do not find a significant difference when looking at this same comparison between the CS+ imagine (M= 4.97, SD=1.54) and CS- imagine (M=5.33, SD=1.35) conditions in the Visual Acquisition phase $t(30)=1.78$, $p=0.09$. These comparisons indicate that the stimuli are all of equal difficulty.

Hypothesis 1. To investigate whether participants generated a subjective fear response to the CS+ imagine stimulus in the Imagine Acquisition phase, an independent t-test showed a significant difference between the imagine CS+ (M=4.58, SD=1.88) and imagine CS- (M=1.97, SD=1.58) condition, $t(30)= 6.352$, $p< .001$ (Figure 6).

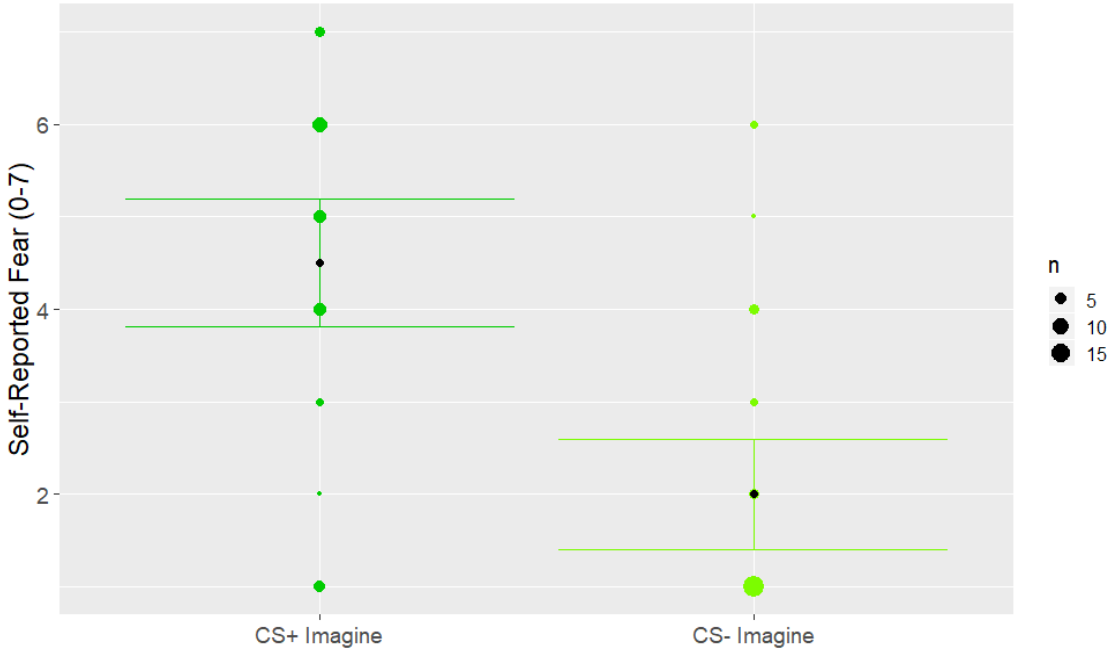


Figure 6. CS+ Imagine and CS- Imagine self-reported fear during Imagery Acquisition. Black dot indicates mean.

Hypothesis 2. An independent t-test was also run on the view CS+ (M= 2.61, SD=2.06) and view CS- (M=1.42, SD= .96) conditions in the Imagine Acquisition condition to determine whether participants generated a subjective fear response to the CS+ view condition (Figure 7). A significant difference was found between these two conditions, $t(30)=3.16$, $p=.003$. This indicates that the subjective fear response acquired to the imagined stimulus generalized to the viewed stimulus.

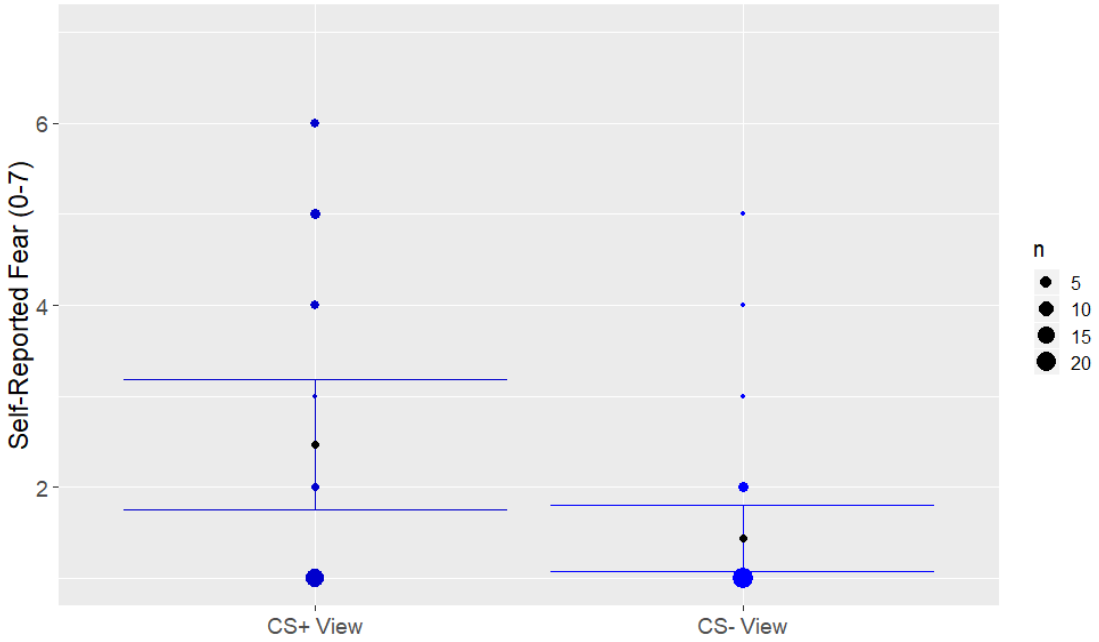
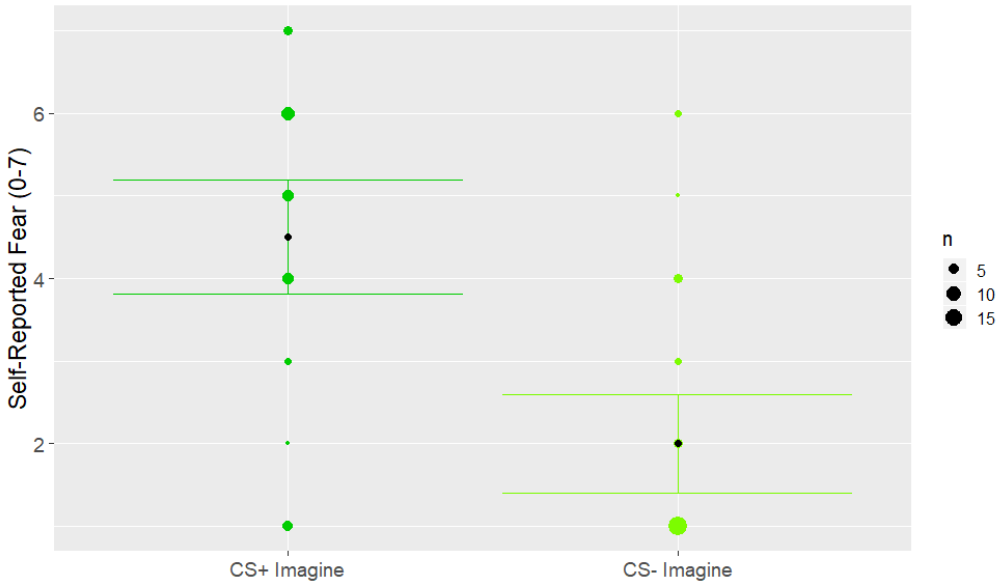


Figure 7. CS+ View and CS- View self-reported fear during Imagine Acquisition. Black dot indicates mean.

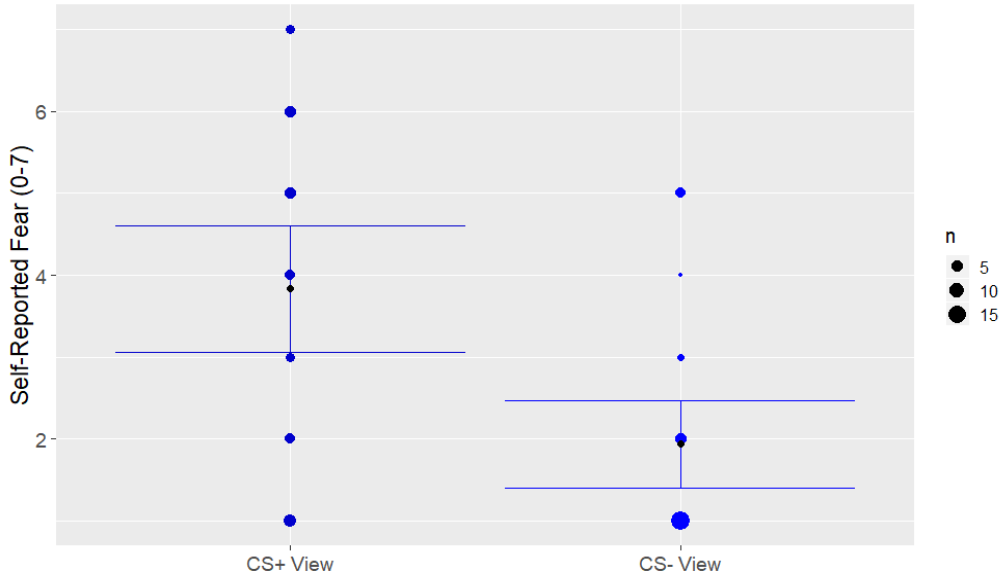
Hypothesis 3. Finally, to address the hypothesis that fear acquired to imagined and fear acquired to viewed stimuli will be similar in magnitude, an independent t-test was run on the CS+ imagine condition from the Imagery Acquisition phase and the CS+ view condition from the Visual Acquisition phase. This test indicated no significant difference when fear is acquired to an imagined stimulus (M=4.5, SD=1.85) and when fear is acquired to a viewed stimulus (M=3.83, SD=2.07), $t(30)=1.67$, $p=.11$.

a 2x2 ANOVA was conducted, with the condition (CS+ and CS-) and set type (Imagine Acquisition task and Visual Acquisition task) as within subject variables (Figure 8). There was a main effect of the condition, $F(1, 30) = 43.73$, $p < .001$ ($M_{CS+} = 4.17$ vs $M_{CS-} = 1.97$), indicating that the CS+ is greater than the CS- regardless of which set it is being presented in. To verify this main effect, follow-up t-tests were run. As in hypothesis 1, an independent t-test showed a

significant difference between the imagine CS+ (M=4.58, SD=1.88) and imagine CS- (M=1.97, SD=1.58) conditions from the Imagery Acquisition phase, $t(30)= 6.352$, $p< .001$. The t-test investigating the view CS+ (M=3.83, SD=2.07) and view CS- (M=1.93, SD=1.44) conditions from the Visual Acquisition phase was also significant, $t(30)=4.83$, $p<.001$. In the 2x2 ANOVA, there was no significant main effect of set type, $F(1, 30) = 2.11$, $p = .16$. This indicates that regardless of which condition was presented, the Imagine Acquisition and Visual Acquisition are not significantly different. There was also no significant interaction of the type of condition and set type, $F(1, 30) = 1.79$, $p = .19$. Due to the significant main effect of condition and lack of significant main effect of set type, this indicates that both sets have similar levels of self-reported fear for their respective CS+ and CS- conditions.



a.



b.

Figure 8. Self-reported fear. A. CS+ Imagine and CS- Imagine self-reported fear during Imagine Acquisition. B. CS+ View and CS- View self-reported fear during Visual Acquisition.
Black dots indicate mean.

fMRI

A whole-brain approach was used for the following analyses.

Hypothesis 1. Similar to the Likert style questionnaire analysis, to determine the ability of participants to acquire fear to an imagined stimulus, a whole-brain analysis between the imagine CS+ condition and the imagine CS- condition from the Imagine Acquisition were compared, resulting in a difference of activation (CS+i – CS-i). This resulted in right insula activation (1487 voxels; max z stat = 3.89; X = 36, Y = 14, Z = -14 ; Figure 9). No significant difference of activation was found in the hippocampus or visual cortex as predicted in the hypotheses.

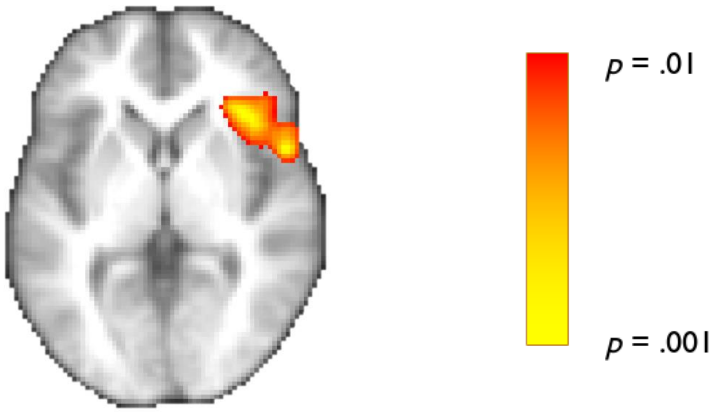


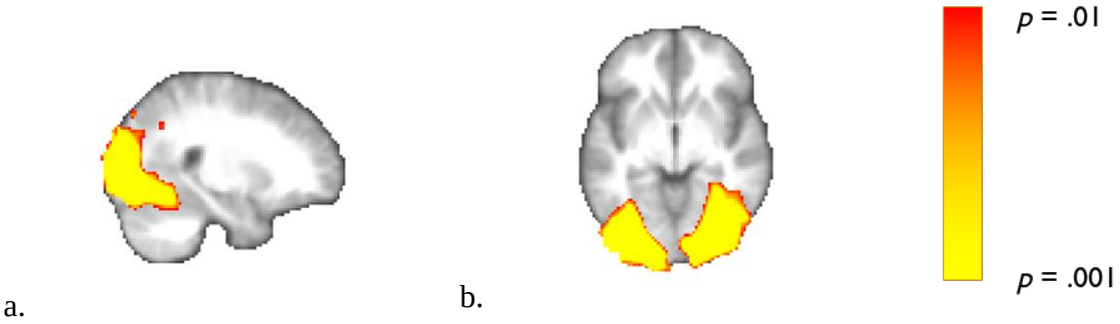
Figure 9. Insula Activation was found in the right insula when comparing CS+ Imagine to CS- Imagine in Imagery Acquisition.

Hypothesis 2. Again, similar to the Likert style questionnaire analysis, to determine if participants generalize the fear acquired in hypothesis 1 to the respective viewed stimulus, the viewed CS+ and viewed CS- conditions from the imagery acquisition set were compared (CS+v – CS-v). Using whole-brain analyses, no significant clusters of activity following thresholding and multiple comparisons correction were found.

Due to no whole brain activation, we conducted a region-of-interest analysis using the right anterior insula cluster we found to be significantly active during the acquisition of fear conditioning to imagined stimuli. This analysis compared the difference of the viewed CS+ and viewed CS- conditions from the imagery acquisition set. No significant difference was found between the viewed CS+ (M= 0.08) and viewed CS- (M=0.20) conditions, $t(1,30) = .92$, $p = .37$.

Hypothesis 3. Two analyses were performed to assess two aspects of the third hypothesis. First, to compare the neural mechanisms of fear acquired to imagined and viewed stimuli, we investigated the interaction between the difference of imagine CS+ and imagine CS- condition from the Imagine Acquisition and the difference between the view CS+ and view CS- condition from the Visual Acquisition [(CS+i – CS-i) - (CS+v – CS-v)]. The whole brain analysis revealed no areas of significant differential activation.

Second, to investigate differential activation in regions associated with imagining versus viewing a fear conditioned stimulus, we compared the imagine CS+ from the Imagine Acquisition and the view CS+ from the Visual Acquisition (CS+i - CS+v). Activation in the visual cortex (9355 voxels; max z stat = 6.3; X = 26, Y = -90, Z = 12; Figure 10) was greater when viewing than imagining. We did not find differential activation in the frontoparietal regions or thalamus for either view or imagine.



a. b.

Figure 10. Activation found in the visual cortex when comparing CS+ Imagine from Imagery Acquisition to CS+ View from Visual Acquisition a. sagittal view b. horizontal view.

A conjunction analysis was used to determine the similar regions of activation between the difference of the imagine CS+ and imagine CS- condition from the Imagine Acquisition (CS+i – CS-i) and regions of activation of the difference of the view CS+ and view CS- condition from the Visual Acquisition (CS+v – CS-v). While the whole-brain and region of interest analyses we conducted previously result in a difference of activation, the conjunction analysis results in activation which is the same between the comparisons, [(CS+i – CS-i) ∩ (CS+v – CS-v)]. Two clusters were found (Figure 11). The first cluster (Figure 11, light blue) was found at the frontal operculum cortex/insular cortex (422 voxels; max z stat = 1; X = 37.4, Y = 22.4, Z = 2.45). The second cluster (Figure 11, dark blue) was found at the central opercular cortex/precentral gyrus (91 voxels; max z stat = 1; X = 56.9, Y = 7.91, Z = 5.52).

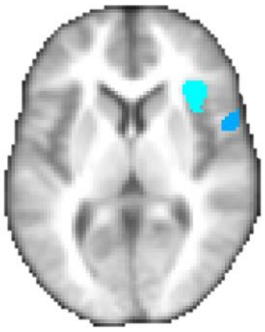


Figure 11. Two clusters, the Frontal Operculum Cortex/Insular Cortex (light blue) and the Central Opercular Cortex/Precentral Gyrus (dark blue) were found in the conjunction analysis of the difference of the imagine CS+ and imagine CS- condition from the Imagine Acquisition phase with the difference of the view CS+ and view CS- condition from the Visual Acquisition phase

Discussion

This study focused on mental imagery in the acquisition and generalization of fear. We did this using 2 tasks. In the Imagine Acquisition task participants were fear conditioned to an imagined stimulus while in the Visual Acquisition task participants were fear conditioned to a viewed stimulus. We assessed the participants' fear subjectively and the underlying neural mechanisms using fMRI. Overall, we found that participants self-reported fear to an imagined stimulus, this fear then generalized to viewing the same stimulus, and the magnitude, as well as the neural mechanisms, of fear are similar when acquiring fear to an imagined or a viewed stimulus.

In this study, we found that participants have a subjective fear when being fear conditioned to an imagined stimulus. When being fear conditioned to an imagined stimulus, neural activation was found in the insula. We also found that this subjective fear generalizes to viewing the same stimulus, even though participants are were never fear conditioned to the viewed stimulus. No neural activation was found during generalization, which leaves the mechanisms for this generalization unknown at this time. Hypothesis 3, tested the similarities and differences when being fear conditioned to an imagined stimulus versus when being fear conditioned to a viewed stimulus. A similar magnitude of self-reported fear is found between the imagined and viewed fear. We also find significant overlapping activation in the insular cortex and precentral gyrus when assessing the neural activation produced by differential fear acquired to an imagined stimulus and fear acquired to a viewed stimulus. Finally, we find greater visual cortex activation when viewing a stimulus than when imagining a stimulus.

Acquiring fear to imagined percepts

The present study demonstrated that participants self-report fear to mental images of visual stimuli. Specifically, participants subjectively reported being more afraid when imagining the CS+ compared to when imagining the CS-. Our findings are consistent with the findings of Lewis et al. (2013), who found that participants can form a learned association during mental imagery as evidence by improved reaction time showing participants accurately associate the pattern with the emotion of the image during the learning phase. Our self-reported findings show that participants are not only able to acquire fear to an imagined stimulus, but also that they are aware of this learned fear and experienced a state of fear.

One limitation of the self-reported fear is that it was acquired at the end of all 6 runs in the session rather than trial-by-trial. Therefore, our self-report results also required a subjective memory component such that participants recall the state they were in during the different conditions. While self-reporting can have limitations such as participant expectations, the consistency with previous research (Lewis et al., 2013) and the fMRI findings indicate that participants did differentially condition to the imagined CS+ compared to the CS-. Moreover, whereas we observed differential self-reported findings for subjective fear, on our other self-reported measures participants did not differentiate between imagery effort or imagery vividness.

Similar to previous research using differential fear conditioning we found that the anterior insula was more activated when forming a mental image of the CS+ compared to the CS- (Lee, Greening, et al. 2018). The insula has also been found in differential conditioning with partial reinforcement (Dunsmoor, Bandettini, & Knight, 2007). More broadly, while most research into fear appears to focus on the role of the amygdala, there are several examples of research implicating the insula including prominent theories of emotion (Damasio & Carvalho,

2013). For example, bilateral insula damage has been shown to have no effect on emotions, including pleasure, happiness, sadness, irritation, and others (Philippi et al., 2012). This has led to a focus on subcortical areas, such as the brain stem, as the primary source for basic emotions. It is now postulated that because the insula is not necessary for emotions, the emotions begin at the brain stem and are represented in the insula (Damasio & Carvalho, 2013). Furthermore, the insula is in a connection to multiple pathways such as memory, language, and reasoning, suggesting the insula may be necessary for the introduction of emotions to cognitive processes. This thinking identifies the insula as the "crosswalk between feelings and cognition" (Damasio & Carvalho, 2013).

Fear generalization following imagery acquisition

The present study demonstrated that participants generalize self-reported fear acquired to an imagined image to viewing the image. Specifically, participants subjectively reported being more afraid of the CS+ view compared to the CS- view, even though they were never conditioned to the view condition. These findings are related to those of Lewis et al. (2013), experiment 1. Lewis et al. (2013) used a method in which generalization must be assumed when participants were tested on the association made between an emotion and imagining. The participants imagined images in the learning phase only and not the testing phase. The results of Lewis et al. (2013) showed that participants did retain the association between the emotion and image as participants had quicker reaction times when the pattern presented matched the image's emotional content, indicating that generalization was found and is possible (Lewis et al., 2013). Our study addressed the limitation of Lewis et al. (2013) in which the generalization from learning to testing was not tested directly. Lewis et al. (2013) included voluntary mental imagery within their association phase but this mental imagery was not used in the testing phase (Lewis et

al., 2013). By having participants imagine the stimulus during testing, we were able to verify that fear is still associated with a stimulus that is viewed, even though the unconditioned stimulus (i.e., the mild shock) was only ever delivered when participants were imagining the CS+. This subjective, self-reported fear also indicates that participants are aware of the fear they have acquired and generalized from the imagined to viewed stimulus.

In terms of the mechanisms for this generalization, the whole brain analysis found no significant clusters of activity following thresholding and multiple comparisons correction. We also conducted a region-of-interest (ROI) analysis using the right anterior insula cluster we found that was significantly active during the acquisition of fear conditioning to imagined stimuli. No significant difference was found between the viewed CS+ and viewed CS- conditions in the right anterior insula cluster.

One possibility is that we require additional subjects to observe the generalization effects with a whole brain analysis. A power analysis conducted prior to the study indicated that 30-40 participants would be necessary to gain appropriate power. With 31 participants collected, it might be necessary to accumulate more participants, increasing the power and allowing these analyses to more accurately reflect the underlying mechanisms.

Comparing fear conditioning to imagined vs viewed percepts

This study found a similarity in magnitude of subjective fear when fear conditioned to viewing a stimulus as compared to when fear conditioned to imagining a stimulus. This could indicate that participants are just as afraid of an imagined image as a viewed image. This finding is novel and has not been investigated previously, even though mental health disorders such as anxiety and PTSD show real life examples of the ability for the mind to generate strong negative emotions to an absent threat stimulus (Arntz, Tiesema, & Kindt, 2007; Shin & Liberzon, 2010).

Treatment plans have been developed using imaginal exposure for PTSD in which patients recall the traumatic event, focusing on senses, thoughts, and emotions that occur. These treatments have been found to be effective in reducing negative effects of PTSD (Mueser, Yarnold, & Foy, 1991; Bryant, Moulds, Guthrie, Dang, & Nixon, 2003; van Minnen & Foa, 2006) This imaginal exposure can also be combined with imagery rescripting in which PTSD patients are to use the imagination to change the traumatic imagined event, giving the patients control of the situation and allowing the imagination to overcome the fear it has created (Arntz et al., 2007; Grunert, Weis, Smucker, & Christianson, 2007; Holmes, Arntz, & Smucker, 2007). Through having this research and a better understanding of fear and mental imagery, we can begin to assess why these treatments work and how to possibly make them even better.

We also found greater activation in the visual cortex when participants view the feared stimulus than when they imagine it. This is consistent with previous research that has shown increased visual cortex activation when viewing stimuli than imagining stimuli as compared to baseline, though they both produce activation (Dijkstra, Bosch, & van Gerven, 2017). It has also been found that the visual cortex is sensitive to viewing various line orientation (Kamitani & Tong, 2005). With determining that the visual cortex is more active when viewing than imagining, further research to investigate the potential of generalizing the feared mental image to various line orientations may allow us to investigate the similarities between the neural networks of imagined and viewed stimuli, particularly when these have strong emotional components.

Why no amygdala?

Many older studies have commonly associated the amygdala with fear and fear conditioning (Büchel, Morris, Dolan, & Friston, 1998; Cheng et al., 2006; Dunsmoor et al., 2007; LaBar et al., 1998; Tabbert, Stark, Kirsch, & Vaitl, 2005). However, recent research is

finding more specificity is needed on the amygdala's role in fear conditioning. A Pavlovian conditioning, positron emission tomography (PET) study found right amygdala activation during masked angry faces when compared to unmasked angry faces (Morris, Ohman, & Dolan, 1998). Another study had a similar finding regarding amygdala and fear in masked images. This particular PET study recruited participants with a fear of snakes or spiders. The study showed images of snakes, spiders, and masked mushrooms. Activation in the left amygdala was found during both feared and non-feared (but fear-relevant) stimuli as compared to the masked mushrooms. There was no difference, however, between the feared and non-feared stimuli, indicating that the amygdala responds to the threat of a stimulus, rather than the feared stimulus itself (Carlsson et al., 2004).

These studies of the amygdala in fear commonly refer to implicit fear, which we now know has different neural mechanisms than explicit fear (Knight, Waters, & Bandettini, 2009). While the amygdala was previously seen as "the fear center of the brain," it does not fully explain fear and there are separate cortical and subcortical pathways that are involved in fear conditioning (LeDoux, 2000). In the study presented, we had participants rate their subjective level of fear. The findings from the self-reported levels of fear indicate that the participants are aware of their increased fear to the CS+ than the CS-, suggesting an explicit fear rather than implicit. Therefore, a lack of finding in the amygdala is not entirely unexpected.

Two meta-analysis on the neural mechanisms involved in fear conditioning not only found no amygdala activation, but also consistently found activation of the anterior insula (Fullana et al., 2016; Mechias, Etkin, & Kalisch, 2010). A study on the activation of the amygdala and insula during fear in participants with and without PTSD also showed similar results in that amygdala activation was found in participants with PTSD, but only insula

activation was shown in healthy participants (Bruce et al., 2012). Yet another study focusing on fear conditioning using auditory CSs found increased insula activation without any amygdala activation (Lee et al., 2018). Even when focusing on music-evoked emotional processing a study found increased insula activation during fear based music but no amygdala activation (Koelsch, Skouras, & Lohmann, 2018).

Over the past roughly 20 years that fMRI has been used to research the inner working of the brain, there has been much improvement and progress not only on the methods and tools used to acquire the images, but also on those used to analyze the data. With newer techniques and increased knowledge on the brain, we must reassess our findings and build upon what we have previously learned. With more knowledge and tools comes better results, which may be what is occurring with our increased understanding of the amygdala and insula in fear. This is a topic that should continue to be studied and improved upon with our increased understanding of fMRI and way to analyze the images.

Future directions

Future research will be needed to determine how specific versus indiscriminate the generalization of fear is. For example, it has been found that conditioned responses can be generalized along perceptual similarity in animals (Guttman & Kalish, 1956). More specifically, fear in humans can generalized across faces that are perceptually similar (Dunsmoor, Mitroff, & LaBar, 2009). Fear learning can also be influenced by similarity in concepts, such as a spider and a spider web (Dunsmoor, White, & LaBar, 2011). What we do not know, however, are the limits of fear generalization in imagination, and if these results previously found in perception also apply to fear during imagination.

Skin conductance response is another possible future analysis. We expect the SCRs to parallel the behavioral findings, indicating that participants produced the greatest fear of imagined CS+ stimuli when fear conditioning to an imagined stimulus. We also expect the SCRs to follow this same pattern while generalizing this fear that was acquired to imagining to viewing the same CS+ stimuli which was never fear conditioned to. In this case, we expect the SCRs to indicate that participants produce a greater fear of viewing the CS+ than viewing the CS- when participants are never fear conditioned to viewing the stimuli. And again, we expect the SCRs to follow the behavioral results in hypothesis 3 in that the SCRs generated when imagining the CS+ when fear is acquired to imagining the stimulus, and the SCRs generated when viewing the CS+ when fear is acquired to viewing the stimulus are similar in magnitude.

As amygdala influences conditioned fear autonomic responses (Cheng et al., 2006; Cheng et al., 2003; Knight et al., 2005) we expect those with higher amygdala activity to also produce higher SCRs. We expect those with higher amygdala activity to produce higher SCRs, though we expect greater activation for the conditioned stimulus than for the generalized stimulus. We expect the SCRs to parallel the behavioral findings, indicating that participants produced the greatest fear of viewed CS+ stimuli while generalizing this fear to imagined CS+ stimuli.

Now that we have determined that fear to an imagined stimulus is similar in magnitude to fear of a present stimulus in hypothesis 3, we need to begin to determine exactly what aspects are similar and different in these two processes. More specifically, for example, does fear extinction occur similarly when extinguishing the fear of an imagined stimulus versus extinguishing the fear of a viewed stimulus? Is extinguishing fear to an imagined stimulus easier or more difficult

than extinguishing the fear of a viewed stimulus? Are the methods for extinguishing fear in imagined stimuli and viewed stimuli similarly effective or should they be treated differently?

Lastly, using MVPA, we can measure the mental imagery of our participants. Previous studies have been able to use MVPA to accurately depict the orientation gratings of imagined stimuli, despite there being low neural activity (Albers et al., 2013; Kamitani & Tong, 2005). This tool allows the neural patterns in visual areas V1 and V2 during perception and can verify the stimuli participants imagine during each trial. This analysis will also further support the relationship between mental imagery and perception.

Conclusion

Through this study, we have discovered that it is possible to generate fear to an imagined stimulus, this fear can then generalize to viewing the same stimulus, and the fear acquired through imagination and perception have a similar magnitude of fear but capitulated by different neural mechanisms. It also provides further support, in addition recent research, of the importance of the insula, rather than the amygdala, in emotions. This could indicate that participants generate a fear response to mental images, this fear is also present when viewing the same image, and fear acquired to mental images and viewed images produce a similar magnitude of fear.

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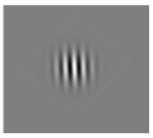
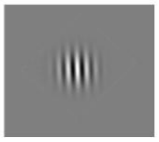
Appendix 1. Imagery Acquisition Phase Likert Style Questionnaire

This questionnaire was presented as a powerpoint to participants in the scanner, in which they are able to verbally communicate their responses to the researcher.

Left:  Vertical: 

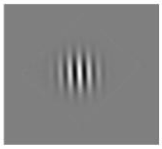
1. How vivid was your mental imagery on IMAGINE LEFT trials?
   [None Existent] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Strong]

2. How vivid was your mental imagery on IMAGINE VERTICAL trials?
   [None Existent] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Strong]

Left:  Vertical: 

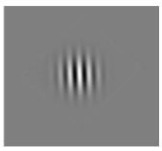
3. How hard did you try to form the mental images on IMAGINE LEFT trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

4. How hard did you try to form the mental images on IMAGINE VERTICAL trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

Left:  Vertical: 

7. How much did you fear the shock on VIEW LEFT trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

8. How much did you fear the shock on VIEW VERTICAL trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

Left:  Vertical: 

5. How much did you fear the shock on IMAGINE LEFT trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

6. How much did you fear the shock on IMAGINE VERTICAL trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

Appendix 2. Visual Acquisition Phase Likert Style Questionnaire

This questionnaire was presented as a powerpoint to participants in the scanner, in which they are able to verbally communicate their responses to the researcher.

Right:  Horizontal: 

1. How vivid was your mental imagery on IMAGINE RIGHT trials?
   [None Existent] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Strong]

2. How vivid was your mental imagery on IMAGINE HORIZONTAL trials?
   [None Existent] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Strong]

Right:  Horizontal: 

3. How hard did you try to form the mental images on IMAGINE RIGHT trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

4. How hard did you try to form the mental images on IMAGINE HORIZONTAL trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

Right:  Horizontal: 

5. How much did you fear the shock on IMAGINE RIGHT trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

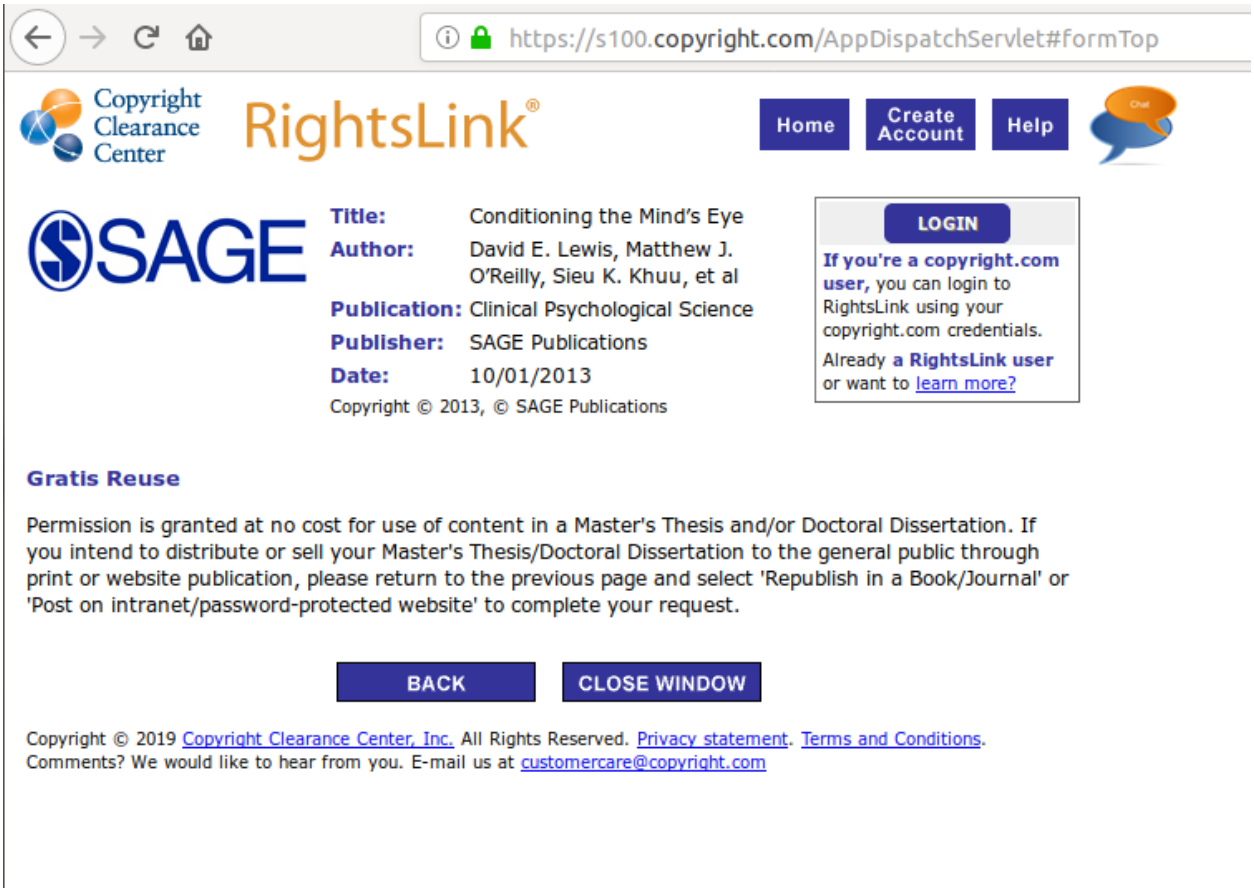
6. How much did you fear the shock on IMAGINE HORIZONTAL trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

Right:  Horizontal: 

7. How much did you fear the shock on VIEW RIGHT trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

8. How much did you fear the shock on VIEW HORIZONTAL trials?
   [Not At All] **1 – 2 – 3 – 4 – 5 – 6 – 7** [Very Hard]

Appendix 3. Figure Permissions



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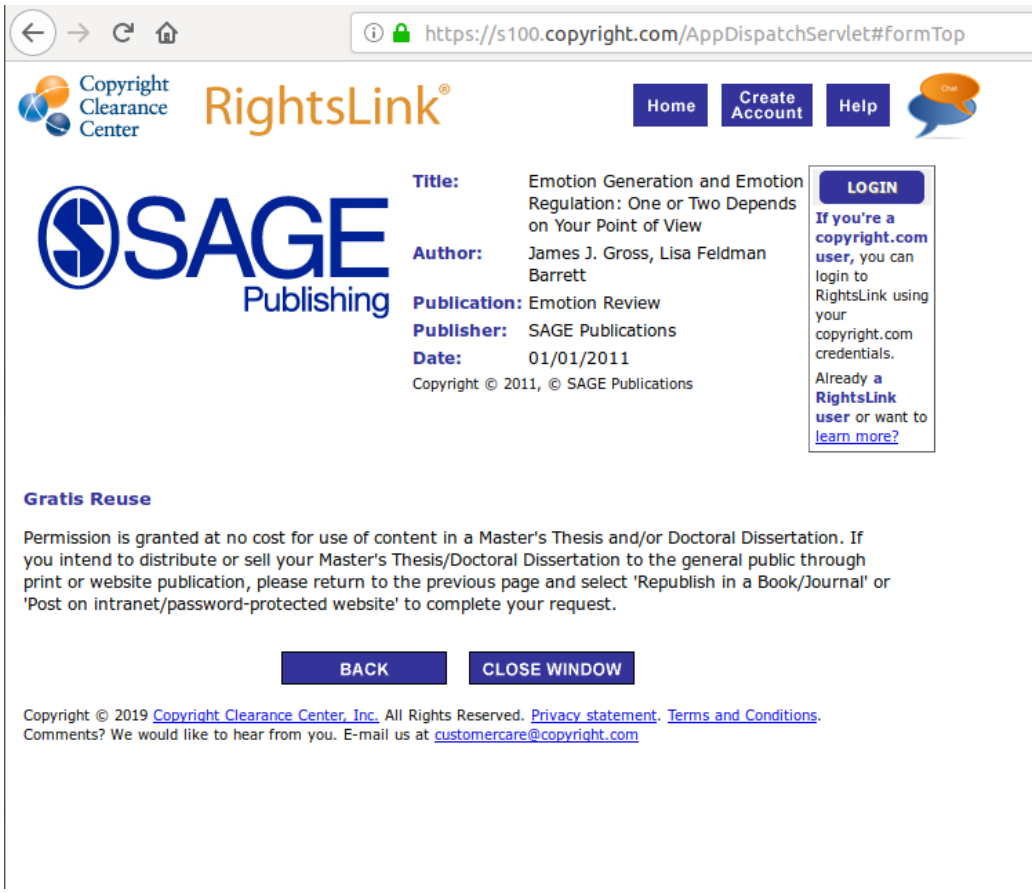

Vita

Lauryn Burleigh, born in Lafayette, Louisiana, completed her Bachelor's of Science at the University of New Orleans in New Orleans, Louisiana. Upon taking a Biopsychology course, her interest in the brain grew, and she began to work in a neuroimaging focused lab. She joined Dr. Steven Greening's lab at Louisiana State University to pursue her interest in researching affect and psychopathology in cognitive neuroscience. After completing her master's, Lauryn will continue to work in Dr. Greening's lab to complete her doctorate.