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Comparing electric shock and a fearful screaming face as unconditioned stimuli for fear learning

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ABSTRACT

The potency of an unconditioned stimulus (UCS) can impact the degree of fear learning. One of the most common and effective UCSs is an electric shock, which is inappropriate for certain populations (e.g., children). To address this need, a novel fear learning paradigm was recently developed that uses a fearful female face and scream as the UCS. The present study directly compared the efficacy of the screaming female UCS and a traditional shock UCS in two fear learning paradigms. Thirty-six young adults completed two fear learning tasks and a measure of trait anxiety; fear learning was indexed with fear-potentiated startle (FPS) and self-reported fear ratings. Results indicated comparable FPS across the two tasks. However, larger overall startle responses were exhibited in the shock task, and participants rated the shock UCS and overall task as more aversive than the screaming female. In addition, trait anxiety was only related to FPS in the fear learning task that employed a shock as the UCS. Taken together, results indicate that, although both UCS paradigms can be used for fear conditioning (i.e., to produce differences between CS+ and CS−), the shock UCS paradigm is more aversive and potentially more sensitive to individual differences in anxiety.

1. Introduction

Fear learning refers to the process by which a neutral stimulus (or CS+) produces a fearful response after being paired with an aversive unconditioned stimulus (UCS). Following fear conditioning, organisms exhibit heightened fear responding when presented with a CS+ (the stimulus that predicts impending threat, or UCS), relative to the CS− (a stimulus that specifically signals safety, or absence of UCS; Davis et al., 1993). Previous studies have consistently used fear-potentiated startle (FPS) to measure fear learning because the magnitude of the eyeblink startle reflex is reliably augmented during fearful states (Hamm et al., 1993; Lang et al., 1990). For instance, in a fear learning paradigm with paired and unpaired conditions, individuals exhibited a heightened startle response (i.e., FPS) during a blue light (the CS+) that had been repeatedly paired with an electric shock (UCS), whereas those in the unpaired condition did not exhibit FPS during the blue light because it did not predict the UCS (Grillon and Davis, 1997).

Notably, the nature of the UCS itself impacts the degree of fear learning. That is, more potent UCSs are related to greater baseline levels of arousal (Grillon et al., 2004), faster fear acquisition (Cook et al., 1986), greater magnitude of the fear response (Cook et al., 1986; Grillon et al., 2004), as well as increased resistance to fear extinction (Cook et al., 1986). Fear conditioning is most successful when the UCS is both potent and survival-relevant (Britton et al., 2010). Thus, a weak UCS may not elicit significant differences in fear learning either within (i.e., between CS+ and CS−) or between individuals (e.g., anxious vs. and non-anxious groups; Britton et al., 2010).

An electric shock is one of the most widely used UCSs in fear learning studies in both human and non-human animals (Brown et al., 1951; Davis et al., 1993; Grillon, 2002). However, a shock may not be a feasible UCS for use with certain populations, such as children and adolescents (referred to collectively as *children*). Instead, alternative, and in some cases milder UCSs, have been used in fear learning paradigms with children, including a loud tone (Craske et al., 2008; Liberman et al., 2006), metal scraping on a slate (Neumann et al., 2008; Waters et al., 2009), or an air blast to the larynx (Borelli et al., 2011; Grillon et al., 1998; Reeb-Sutherland et al., 2009). However, the magnitude of fear learning using these shock-alternative UCSs has been variable across studies.

In an effort to create an appropriate and effective fear conditioning paradigm for children, Lissek et al. (2005a) developed a novel UCS — a fearful female face paired with a shrieking female scream (also see Grillon et al., 2008; Lau et al., 2008). This novel and survival-relevant UCS has successfully elicited greater fear responses during CS+ relative to CS− when indexed by subjective fear ratings (Lau et al., 2008) and startle responses (Glenn et al., 2012; Schmitz et al., 2011). Although the screaming female UCS paradigm has been found to be comparable

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to an alarm, a loud tone, and white noise, as measured by subjective ratings of fear (Britton et al., 2010), previous studies have not examined how this novel UCS compares to the potency of an electric shock. In addition, no studies have compared the screaming female UCS to other UCSs using fear-potentiated startle — one of the most reliable physiological measures of fear learning (Lang et al., 1990).

Therefore, the main purpose of the current study was to examine the efficacy of the screaming female UCS paradigm compared to the more commonly used electric shock UCS. Although an electric shock is a more noxious UCS, the screaming female UCS may have its own unique strengths. In particular, the screaming female may be a more survival-relevant UCS than an electric shock. Survival relevance refers to the likelihood of a particular stimulus to have served as a consistent threat throughout history (Ohman and Mineka, 2001); for instance, a snake would be considered a more survival-relevant stimulus than a flower. Moreover, stimuli that are relatively newer threats, such as weapons (or in this case, electric shocks), may not elicit the same magnitude of fear response compared to more longstanding threats to survival, such as predatory animals (or in this case, social cues that signal threat in the environment; see reviews: Ohman, 1986; Ohman and Mineka, 2001; Seligman, 1971). Given that the two UCSs may be advantageous for different reasons, we hypothesized that participants would exhibit similar fear learning patterns (i.e., differences between CS+ and CS− startle magnitudes) when either UCS paradigm was utilized. In addition, we expected self-reported ratings of fear to be higher for CS+ than CS− in both tasks, but not significantly different between the two paradigms.

Notably, a large and growing literature has linked dysfunction in fear learning to the development and maintenance of anxiety disorders in adults (Britton et al., 2010; Lissek et al., 2005b; Mineka and Oehlberg, 2008). A recent meta-analysis of fear learning studies with adult anxiety patients indicates that the link between anxiety and fear learning is complex (Lissek et al., 2005b). In simple fear conditioning studies where only a threat cue (CS+) is presented, anxiety is related to greater fear acquisition. However, in discrimination paradigms where both threat and safety cues are presented (CS+ compared to CS−), anxiety is related to overall larger startle magnitudes but not to greater fear learning. Given the association between anxiety and fear acquisition in simple conditioning designs, Lissek et al. (2005b) suggested that the lack of fear conditioning differences in discrimination paradigms may be due to elevated responses during safety cues (CS−), and thus may indicate generalization of the fear response. Although much less is known about the pathophysiology of anxiety disorders in children, fear learning studies in this population indicate that the associations between anxiety and fear learning may be similar to those found in adults. That is, previous studies have found that children with anxiety disorders (Lau et al., 2008) and adolescent females at high-risk for anxiety disorders (Grillon et al., 1998) exhibit elevated startle magnitudes across all stimuli, rather than greater fear acquisition specifically.

Given the increasing use of the screaming female UCS paradigm to examine fear learning in children (e.g., Glenn et al., 2012; Lau et al., 2008; Schmitz et al., 2011), it is important not only to examine how the UCS paradigm compares to an electric shock UCS, but also to assess whether it is sensitive to individual differences in anxiety. Therefore, a secondary goal of the present study was to examine how FPS in the two UCS paradigms related to trait anxiety. Based on existing research in adults and children, we predicted that trait anxiety would be related to greater overall startle magnitudes across the two tasks.

2. Materials and methods

2.1. Participants

The original sample consisted of 47 young adults recruited from a college population. Eleven participants were excluded from analyses for the following reasons: (a) stopping the startle task before it concluded ($n=1$), (b) failing to exhibit any measurable startle response on 2/3 of trials ($n=3$), (c) excessive artifacts during the baseline period (the 50 ms period before the onset of the startle probe; $n=5$), and (d) outliers in the startle data (i.e., startle magnitudes more than 2 standard deviations above or below the mean; $n=2$).

The final sample included 36 participants (25 female). The average age of the sample was 19.44 ($SD=1.89$), and the largest ethnic groups were Caucasian (41.7%), Asian (27.8%), and Hispanic (16.7%). Participants excluded from the analyses were not significantly different from participants included in the analyses based on age ($t[45]=0.71$, $p=.481$) or gender ($\chi^2[1, N=47]=0.83$, $p=.361$). However, there were ethnicity differences between the two groups: included participants were less likely to be African American ($\chi^2[1, N=47]=6.49$, $p=.011$) and more likely to be Caucasian ($\chi^2[1, N=47]=3.98$, $p=.046$) than participants excluded from the analyses.

2.2. Stimuli and presentation

2.2.1. Faces task

The fear learning stimuli used in this task were based on Lau et al. (2008). The task described below was recently used to measure fear learning in 8 to 13 year-olds (Glenn et al., 2012). In this task, the CS+ and CS− were two neutral female faces (NimStim: 01F, 03F; Tottenham et al., 2009); CSs were counterbalanced across participants. The UCS was a fearful female face (same actress as the neutral CS+) paired with a loud female scream. The UCS scream was presented over computer speakers and was experienced by the participant (at the ear while wearing headphones) at approximately 80 dB for 1 s. On 75% of CS+ trials, the CS+ was reinforced with the UCS; on these trials, the neutral CS+ face was presented for six seconds, and then replaced by the fearful female face for an additional three seconds, and this switch was accompanied by the loud female scream.

2.2.2. Shapes task

In this task, the CS+ and CS− were a square and a circle; again, CSs were counterbalanced across participants. The UCS was a shock delivered to the participant's left tricep with an electric stimulator (Contact Precision Instruments) that presented 60 Hz constant AC stimulation between 0 and 5 mA for 500 ms. The level of shock was chosen by each participant to be a level that was highly uncomfortable, but still tolerable (see Procedure for details). CS+ trials were reinforced with the UCS, immediately after the offset of the CS+, on 75% of CS+ trials.

2.2.3. Faces and shapes tasks

There were eight CS+ and eight CS− trials, and CS− trials were never followed by the UCS. CSs were presented for six seconds and intertrial intervals (ITIs; CS offset to CS onset) ranged from 10 to 12 s. For each task, three pseudorandom trial orders were constructed and randomized between participants. The startle reflex was elicited with auditory startle probes — 50 ms, 105 dB bursts of white noise with instantaneous rise/fall time — which were presented binaurally through headphones using a noise/tone generator (Contact Precision Instruments; Cambridge, MA). Startle probes were presented during six of the eight CS+ and six of the eight CS− trials, 3.5–4.5 s after picture onset. However, CS+ reinforced trials and startle trials were not always the same; that is, the presence of a startle probe did not predict the UCS. In addition, startle probes were presented during four ITIs in each task.

Visual stimuli were presented with Presentation software (Neurobehavioral Systems, Inc; Albany, CA) on a 19-inch monitor 23 in. from the participant. Stimuli occupied 4 in. vertically and 2.5 in. horizontally of the computer screen. In the Faces task, visual stimuli were presented in gray scale; in the Shapes task, visual stimuli were presented in royal blue against a black background. Speakers, delivering