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The effects of contextual threat and anxiety on affective startle modulation

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ABSTRACT

The startle reflex is attenuated and potentiated when participants are viewing pleasant and unpleasant images, respectively. Research demonstrates that threatening contexts also potentiate startle, but it remains unclear how a threatening context might impact startle modulation to emotional images, especially as a function of trait anxiety. The present study measured startle reactivity while 43 participants viewed pleasant, unpleasant, and neutral images across conditions of threat-of-shock and safety (i.e., no shock). Compared to neutral images, startle was potentiated during unpleasant images and attenuated during pleasant images. Threat-of-shock potentiated startle during all picture types, suggesting that threat-of-shock broadly sensitized the defensive system but did not change affective modulation of startle. Lastly, higher levels of trait anxiety were associated with less startle potentiation during unpleasant images across both conditions—a finding in line with previous research demonstrating deficient threat mobilization in response to unpleasant stimuli among highly anxious individuals.

1. Introduction

The defensive startle response is a cross-species reflex elicited by abrupt and intense sensory stimuli. In humans, the startle response is most notably evidenced by rapid eye closure, and this eye blink reflex is modulated by the motivational state of the individual (Grillon & Baas, 2003; Landis & Hunt, 1939; Lang, Bradley, & Cuthbert, 1997). Specifically, the startle reflex is potentiated when an individual's aversive motivational system is primed, and attenuated when the appetitive motivational system is primed (Lang et al., 1997). A large literature has established that viewing arousing unpleasant pictures (e.g., scenes of human threat, animal attack, or mutilation) significantly potentiates the startle reflex, whereas viewing arousing pleasant pictures (e.g., happy babies, smiling faces, or erotica) attenuates the reflex (see Lang, 1995; Lang et al., 1997).

Affective modulation of startle has similarly been demonstrated when participants view expressive faces. For instance, viewing angry faces has been shown to potentiate startle (Dunning, Auriemmo, Castille, & Hajcak, 2010; Hess, Sabourin, & Kleck, 2007; Springer, Rosas, McGetrick, & Bowers, 2007); however, other types of aversive faces (e.g., fearful expressions) do not reliably potentiate the startle reflex (Anokhin & Golosheykin, 2010; Dunsmoor, Mitroff, & LaBar, 2009; Grillon & Charney, 2011; Springer et al., 2007). Recent work has suggested that aversive faces may not engage the defensive motivational system to the same degree as highly unpleasant scenes. For instance, when viewing facial expressions and pictures from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005), participants rated expressive faces lower on dimensions of arousal and valence compared to IAPS (Britton, Taylor, Sudheimer, & Liberzon, 2006). Moreover, in a direct comparison of IAPS and emotional faces, Wangelin, Bradley, Kastner, and Lang (2012) found that facial expressions did not activate affective physiological responses (i.e., startle response, skin conductance, and event related potentials) as strongly as emotional scenes.

In addition to unpleasant pictures, the startle reflex is also potentiated in the presence of a variety of other unpleasant, arousing stimuli. For instance, conditioned stimuli that predict an electric shock can prime the defensive motivational system, leading to potentiated startle response (Brown, Kalish, & Farber, 1951; Davis, Falls, Campeau, & Kim, 1993; Davis, 2006; Grillon & Baas, 2003; Grillon & Davis, 1997). Startle magnitude can track the generalization (Hajcak et al., 2009; Lissek et al., 2008, 2010) and extinction (Alvarez, Johnson, & Grillon, 2007; Orr et al., 2000; Vansteenwegen, Crombez, Baeyens, & Eelen, 1998) of conditioned stimuli as well. Further, cues that predict other forms of aversive states, like difficulty in respiration, have also led to potentiation of the startle reflex (Lang et al., 2011).

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In addition to foreground stimuli, threatening contexts also engage the defensive motivational system. For example, threat-of-shock compared to safe (i.e., no-shock) experimental conditions reliably potentiate the startle reflex (Bradley, Moulder, & Lang, 2005; Bradley, Silakowski, & Lang, 2008; Grillon, Ameli, Woods, Merikangas, & Davis, 1991); startle was higher in amplitude during conditions when participants anticipated an electric shock compared to when shocks were not anticipated, and these effects were evident prior to the actual delivery of a single shock (Grillon et al., 1991). In a fear conditioning paradigm using virtual reality environments, Grillon et al. (2006) had participants explore three different contexts: a room where no shocks would occur, a room with predictable shocks, and a room with unpredictable shocks. Anxiety ratings were highest in the room with unpredictable shocks—and the baseline startle reflex was largest in the context with unpredictable aversive shocks compared to the other two rooms (Grillon, Baas, Cornwell, & Johnson, 2006). Other forms of contextual threat, such as the threat of aversive abdominal stimulation (Hubbard et al., 2011; Naliboff et al., 2008) or a strenuous hyperventilation challenge (Melzig, Holtz, Michalowski, & Hamm, 2011), also potentiate the startle reflex.

Thus, the startle reflex is potentiated when participants view unpleasant visual stimuli, stimuli that predict punishment or aversive states, and when participants are in threatening contexts. However, much less work has been done examining how unpleasant visual stimuli and threatening contexts might interact to impact the defensive startle reflex, although existing research suggests several possibilities. One possibility is that contextual threat may selectively sensitize defensive responding during aversive stimuli, but have little or no effect on defensive responding during pleasantly valenced stimuli. In support of this possibility, Grillon and Charney (2011) had participants view fearful and neutral faces during alternating phases of threat-of-shock or safety (happy faces were also compared to neutral faces, but in a separate testing session). Fearful faces potentiated startle during the threat-of-shock condition, but not during a safety condition. These data suggest that a threatening context may uniquely sensitize defensive mobilization to threatening foreground stimuli; indeed, it would seem adaptive for defense mechanisms to respond selectively to potentially harmful or aversive stimuli under conditions of heightened threat (Grillon & Charney, 2011).

A second possibility is that contextual threat may sensitize defensive responding, regardless of foreground stimulus valence. For example, participants in a non-stressful control group demonstrated greater amygdala reactivity to angry and fearful faces compared to happy faces (van Marle, Hermans, Qin, & Fernández, 2009); however, for participants undergoing an acute stress induction, amygdala response was equally enhanced for all affective faces (angry, fearful, and happy; van Marle et al., 2009). Other lines of work also support the notion that threat-of-shock may indiscriminately sensitize the processing of all sensory stimuli, as evidenced by increased amygdala and insula activity (Cornwell et al., 2007) and increased brainstem auditory evoked potentials (Baas, Milstein, Donlevy, & Grillon, 2006). Taken together, these data suggest that a stressful or threatening context may sensitize defensive reactivity to all stimuli, at a loss of stimulus specificity.

The primary aim of the present study was to examine how a threatening context would impact the well-established pattern of startle modulation to arousing affective pictures. To this end, we measured startle reactivity while participants viewed pleasant, unpleasant, and neutral images across conditions of threat-of-shock and safety. We expect that during the safety condition, startle response will be attenuated during pleasant pictures and potentiated during unpleasant pictures. Considering the previously reviewed literature, two competing hypotheses emerge for defensive reactivity during the threat-of-shock condition: (1) if threatening contexts activate defensive reactivity uniquely to aversive stimuli, then startle response should be increasingly potentiated only during the unpleasant pictures; and (2) if threatening contexts sensitize the processing of stimuli indiscriminately, then startle response during all picture types should be potentiated, but the pattern of affective modulation should remain intact.

Lastly, it would be fruitful to examine whether individual differences in anxiety might impact affective startle modulation in the presence and absence of threat-of-shock. Some evidence exists for associations between enhanced startle potentiation and individual differences in anxiety-related traits, such as increased levels of fearfulness, behavioral inhibition, and harm avoidance (as reviewed in Grillon & Baas, 2003). Yet other studies find no associations between startle modulation and characteristics of anxiety, including anxious apprehension and defensiveness (Nitschke et al., 2002) and negative affectivity (Cook, Davis, Hawk, Spence, & Gautier, 1992). The relation between startle and trait anxiety (e.g., scores on the trait scale of the STAI) in particular remains unclear in existing literature. For instance, in a threat-of-shock study involving healthy participants, Grillon, Ameli, Foot, and Davis (1993) found no association between fear-potentiated startle response and trait anxiety. In a social threat paradigm, startle magnitude in anticipation of giving a speech was positively correlated with trait *social* anxiety, but not general trait anxiety (Cornwell, Johnson, Berardi, & Grillon, 2006). Among clinical samples, startle was not related to trait anxiety in a threat-of-shock paradigm among PTSD patients (Grillon, Morgan, Davis, & Southwick, 1998). However, when focused on a subgroup of PTSD patients (i.e., those having experienced multiple compared to single traumas), McTeague et al. (2010) found that *reduced* startle reactivity to aversive imagery was concomitant with greater trait anxiety and depressive comorbidity. Moreover, among a large sample of patients with a variety of anxiety disorders (specific phobia, social phobia, panic disorder, and generalized anxiety disorder), *lower* levels of trait anxiety were found to predict *larger* startle reactivity during fearful imagery (Lang & McTeague, 2009). Given these findings, more work is needed to clarify the relation between defensive startle reactivity and trait anxiety. Hence, a secondary and exploratory aim of this study is to examine how individual differences in trait anxiety may relate to affective startle modulation under contexts of threat-of-shock and safety.

2. Methods

2.1. Participants

Fifty-two undergraduate students participated in the present paradigm. Of those, nine were excluded from analysis due to poor quality physiological recordings (excessive EMG artifacts and/or startle non-responders), leaving 43 participants (30 female and 13 male) with a mean age of 20.02 ($SD = 2.55$) in the present study. All participants gave written informed consent and received course credit for their participation. This research was approved by the Stony Brook University Institutional Review Board.

2.2. Stimuli

Fifty-four pictures from the International Affective Picture System (IAPS; Lang, Bradley, et al., 2005) were selected: 18 unpleasant images that depicted threat (e.g., knife attacks), 18 pleasant images that depicted erotica (e.g., nude couples), and 18 neutral images that included people (e.g., working at a computer desk).[1] Normative valence ratings significantly differed between all categories of picture content: pleasant ($M = 6.57$, $SD = 0.43$) and neutral ($M = 5.45$, $SD = 0.36$; $t(34) = 8.50$, $p < 0.001$, $d = 2.82$), unpleasant ($M = 2.85$, $SD = 0.64$) and neutral ($t(34) = -15.02$, $p < 0.001$,

[1] The numbers of the IAPS pictures used were the following: pleasant (4604, 4647, 4651, 4652, 4658, 4659, 4660, 4664, 4668, 4669, 4670, 4677, 4680, 4687, 4693, 4697, 4800, 4810), unpleasant (1050, 1120, 1205, 1300, 1304, 1932, 6230, 6231, 6243, 6244, 6250, 6300, 6350, 6370, 6550, 6563, 6570, 9425), and neutral (2026, 2036, 2038, 2191, 2214, 2374, 2384, 2575, 2580, 5390, 7033, 7041, 7081, 7140, 7500, 7504, 7513, 7546).