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Effects of anticipated emotional category and temporal predictability on the startle reflex

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ABSTRACT

Anticipated emotional category and temporal predictability are key characteristics that have both been shown to impact psychophysiological indices of defensive motivation (e.g., the startle reflex). To date, research has primarily examined these features in isolation, and it is unclear whether they have additive or interactive effects on defensive motivation. In the present study, the startle reflex was measured in anticipation of low arousal neutral, moderate arousal pleasant, and high arousal unpleasant pictures that were presented with either predictable or unpredictable timing. Linear mixed-effects modeling was conducted to examine startle magnitude across time, and the intercept at the beginning and end of the task. Across the entire task, the anticipation of temporally unpredictable (relative to predictable) pictures and emotional (relative to neutral) pictures potentiated startle magnitude, but there was no interaction between the two features. However, examination of the intercept at the beginning of the task indicated a Predictability by Emotional Category interaction, such that temporal unpredictability enhanced startle potentiation in anticipation of unpleasant pictures only. Examination of the intercept at the end of the task indicated that the effects of predictability and emotional category on startle magnitude were largely diminished. The present study replicates previous reports demonstrating that emotional category and temporal predictability impact the startle reflex, and provides novel evidence suggesting an interactive effect on defensive motivation at the beginning of the task. This study also highlights the importance of examining the time course of the startle reflex.

1. Introduction

Psychophysiology has played a prominent role in the measurement of individual differences in emotion and motivation. For example, the startle eye blink reflex is a widely used tool for assessing defensive motivation (Blumenthal et al., 2005; Grillon and Baas, 2003). The startle reflex is modulated by current emotional state, and this has often been demonstrated during the presentation of emotional pictures. Specifically, the startle reflex is potentiated while viewing unpleasant pictures relative to neutral pictures, but is attenuated while viewing pleasant pictures relative to neutral pictures (Lang et al., 1990; Lang, 1995). The *anticipation* of viewing temporally predictable emotional pictures produces a different pattern of results, such that the startle reflex is increased in anticipation of both pleasant and unpleasant pictures relative to neutral pictures (Dichter et al., 2002; Sabatinelli et al., 2001; Sege et al., 2014). These findings suggest that while the startle reflex is sensitive to stimulus valence during picture perception, the anticipation of both pleasant and unpleasant pictures relative to neutral pictures primes defensive motivation.

Predictability is another feature of stimuli that has been suggested to impact defensive motivation (Davis et al., 2010; Grillon et al., 2004). In the laboratory this has often been examined using a no, predictable, and unpredictable (NPU) threat task (Schmitz and Grillon, 2012) that includes three within-subject conditions: no threat (no aversive stimulus is presented), predictable threat (aversive stimulus is signaled by a short duration cue), and unpredictable threat (aversive stimulus is unsignaled). Across all three conditions the startle reflex is measured as a psychophysiological indicator of defensive motivation. A growing number of studies have found that the startle reflex is potentiated in anticipation of both predictable and unpredictable threat relative to no threat (Grillon et al., 2004; Moberg and Curtin, 2009; Nelson and Shankman, 2011)—though startle potentiation appears to be larger in anticipation of unpredictable than predictable threat (Gorka et al., 2016; Nelson et al., 2015).

The NPU task has been exclusively used with aversive or threatening stimuli, including shocks (Bradford et al., 2013; Nelson et al., 2015; Shankman et al., 2013), noises (Nelson and Hajcak, 2017; Schmitz et al., 2011), airblasts (Grillon et al., 2004), and a breathing occlusion (Schroijen et al., 2016). However, predictability has also been shown to impact the processing of appetitive or pleasant stimuli (Berns et al., 2001). Although the NPU task includes a no threat comparison

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condition, it is unclear whether predictability also modulates defensive motivation in anticipation of pleasant and neutral stimuli. Emotional category and temporal predictability are orthogonal characteristics that have both been shown to impact the startle reflex in anticipation of viewing pictures, but no study has examined whether they produce additive or interactive effects on defensive motivation. If predictability impacts defensive motivation irrespective of emotional category, then it is possible that paradigms like the NPU task could be employed with less noxious (i.e., neutral or pleasant) stimuli. However, if there is an interaction between emotional category and predictability, such that unpredictability enhances defensive motivation to a greater degree for more aversive relative to less aversive stimuli, it would suggest that emotional category is an important characteristic to take into consideration in experimental design.

The present study employed a within-subjects design and examined the effect of anticipated emotional category and temporal predictability on defensive motivation. To this end, the startle reflex was measured during the anticipation of low arousal neutral, moderate arousal pleasant, and high arousal unpleasant pictures that were presented with either predictable or unpredictable timing. The startle reflex is an advantageous tool for examining online defensive motivation, but there are two features that are important to consider. First, startle paradigms often involve missing values due to blink or motion artifacts (e.g., participant is blinking while a startle probe is being delivered), which can vary between participants and/or experimental conditions. Second, the startle reflex habituates (i.e., decreases) over time (Gorka et al., 2015; Nelson et al., 2015), and condition effects may be more or less pronounced at different times during the task. To address these issues, the present study employed linear mixed-effects modeling to examine startle magnitude across time, and the intercept at the beginning and end of the task. Multilevel modeling is an advantageous analytic approach as it allows time to be modeled continuously, accounts for the variability in duration between startle probes, and handles missing data by weighting slope estimates by the number of observations (Goldstein, 2011).

We had three primary hypotheses. First, we hypothesized the startle reflex would be potentiated in anticipation of both moderate arousal pleasant and high arousal unpleasant pictures relative to low arousal neutral pictures. Second, we hypothesized that the startle reflex would be potentiated in anticipation of pictures that were presented with unpredictable relative to predictable timing. Finally, we hypothesized there would be an Emotional Category by Predictability interaction, such that unpredictable relative to predictable timing would enhance startle potentiation more in anticipation of high arousal unpleasant pictures compared to low arousal neutral and moderate arousal pleasant pictures. There were no specific hypotheses whether these effects would be present across time, at the beginning of the task, and/or at the end of the task.

2. Method

2.1. Participants

The sample included 95 undergraduates from Stony Brook University who participated for course credit. Exclusion criteria were a history of hearing loss or an inability to read or write English. The sample was on average 20.34 years old (SD = 1.93) and was comprised of 64 females. The racial/ethnic distribution was 32.6% Caucasian, 8.4% African-American, 12.6% Latino, 36.8% Asian, and 9.5% 'Other'. All participants provided informed consent and the study protocol was approved by the Stony Brook University Institutional Review Board.

2.2. Stimuli

Forty-eight color low arousal neutral, moderate arousal pleasant, and high arousal unpleasant pictures (16 per category) were selected from the International Affective Picture System (IAPS; Lang et al., 2008).[1] Each picture was presented for a duration of 2 s. Acoustic startle probes were presented using PSYLAB (Contact Precision Instruments, London, UK) and consisted of a 103 dB burst of white noise with near instantaneous rise time and a duration of 40 ms presented binaurally through headphones.

2.3. Procedure

After electrode placement, participants completed a 180-s baseline habituation task during which four acoustic startle probes were administered. Next, participants received instructions and completed two blocks of the picture-viewing task.

2.3.1. Picture-viewing task

The picture-viewing task was a variant of the NPU threat task (Schmitz and Grillon, 2012), modified so that participants anticipated viewing neutral, pleasant, and unpleasant pictures that were presented with either predictable or unpredictable timing. The task used a within-subjects design and contained six different conditions: predictable neutral picture, unpredictable neutral picture, predictable pleasant picture, unpredictable pleasant picture, predictable unpleasant picture, and unpredictable unpleasant picture. Text at the bottom of the computer monitor informed participants of the current condition by displaying the following information: "neutral picture at 1," "neutral picture at any time," "pleasant picture at 1," "pleasant picture at any time," "unpleasant picture at 1," or "unpleasant picture at any time." Each condition lasted 63 s, during which a 5-s visual countdown was presented four times. The interstimulus interval (i.e., time between countdowns) ranged from 6 to 12 s ($M = 9$ s) during which only the text describing the condition was on the screen. In the predictable condition, pictures were presented when the countdown reached 1. In the unpredictable condition, pictures were presented at any time (during the countdown or interstimulus interval). Across both types of trials participants always knew the emotional category (neutral, pleasant, or unpleasant) of the picture that was about to appear. Startle probes were presented during both the countdown (1 to 4 s following countdown onset) and interstimulus interval (4 to 10 s following interstimulus interval onset). During the task instructions, participants completed one practice trial of each condition (predictable neutral picture, unpredictable neutral picture, predictable pleasant picture, unpredictable pleasant picture, predictable unpleasant picture, and unpredictable unpleasant picture). No startle probes were administered during the practice trials, and the pictures shown during the practice trials were not included in the actual task.

The task consisted of two presentations of each 63-s condition, during which the countdown appeared four times. Participants received startle probes during three out of the four countdown and interstimulus interval presentations. Emotional category order and predictability order were counterbalanced across participants. Each condition (predictable neutral picture, unpredictable neutral picture, predictable pleasant picture, unpredictable pleasant picture, predictable unpleasant picture, and unpredictable unpleasant picture) was presented twice across two blocks, with a short break (30 s) between blocks. All participants received 72 startle probes, with an equal number of startle probes occurring during each condition (12 each) and across the countdown and interstimulus interval (36 each).

[1] The IAPS images included objects (7002, 7003, 7010, 7012, 7017, 7021, 7025, 7032, 7040, 7052, 7061, 7090, 7175, 7211, 7235, 7950) for neutral pictures (valence $M = 5.00$, $SD = 0.22$; arousal $M = 2.95$, $SD = 0.70$), food (7200, 7330, 7340, 7350, 7405, 7451, 7461, 7470) and affiliative scenes (2091, 2154, 2156, 2158, 2274, 2391, 2550, 4626) for pleasant pictures (valence $M = 7.26$, $SD = 0.54$, arousal $M = 4.89$, $SD = 0.66$), and mutilation (3030, 3051, 3071, 3000, 3100, 3110, 3170, 3266) and threat scenes (2811, 6242, 6244, 6250, 6350, 6510, 6560, 9425) for unpleasant pictures (valence $M = 2.10$, $SD = 0.49$, arousal $M = 6.58$, $SD = 0.60$).