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Startle reflex potentiation during aversive picture viewing as an indicator of trait fear

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Abstract

Measures of fearfulness and measures of psychopathy show positive and negative associations, respectively, with startle reflex potentiation during unpleasant picture viewing. We tested the hypothesis that a common bipolar trait dimension underlies these differing associations. Blink responses to noise probes were recorded during pleasant, neutral, and unpleasant pictures in 88 undergraduates assessed with a battery of self-report scales indexing fear and psychopathy/fearlessness. A significant positive association was found between an omnibus index of fear, consisting of scores on the first component from a principal components analysis of these various scales, and startle potentiation during aversive picture viewing. This association was most robust, across participants overall and within gender subgroups, for scenes that were most directly threatening. Implications for psychophysiological research on individual differences and psychopathology are discussed.

Descriptors: Startle blink reflex, Affective pictures, Individual differences, Fear

The potentiation of the startle blink reflex in the presence of aversive stimuli is a well-documented finding in both animal and human literatures. Research with humans has provided evidence of individual differences in the magnitude of this effect. One line of research has demonstrated positive associations between the degree of aversive startle potentiation and measures of dispositional fear and negative affect. Another has demonstrated negative associations between the magnitude of aversive startle potentiation and psychopathy (psychopathic personality), a clinical construct believed to entail deficits in fear reactivity. The current study was undertaken to bridge these two lines of research by investigating the relationship between affective modulation of the startle blink reflex and a bipolar trait dimension defined by measures of dispositional fear on one hand and measures of fearlessness/psychopathy on the other. The primary study hypothesis was that aversive startle potentiation would serve as a continuous physiological indicator of this bipolar trait dimension.

Potentiated Startle as an Index of Fear

Contemporary theories of emotion consider motivational states to be organized around two basic survival systems, one defensive and the other appetitive in nature (Lang, Bradley, & Cuthbert, 1997). The defensive system is activated in situations in which an organism is threatened or endangered. Studies of animals have shown that threatening stimuli activate subcortical circuitry in the brain, including the basolateral and central nuclei of the amygdala (e.g., Campeau & Davis, 1995; Sananes & Davis, 1992). The central nucleus of the amygdala in turn projects to other brain areas that mobilize (depending on the circumstances) varying defensive responses, including freezing, active flight (Fanselow, 1994), fear bradycardia (e.g., Kapp, Frysinger, Gallagher, & Haselton, 1979), blood pressure increase (e.g., LeDoux, 1990), and potentiation of the startle response (e.g., Davis, 2000). From this perspective, individual differences in fear and negative affect can be conceptualized as variations in the readiness of the defensive system to become activated in the presence of cues signaling danger or threat.

In particular, startle reflex potentiation—defined as the enhancement of the startle reflex during exposure to aversive stimulus cues in comparison with nonemotional cues—has been used widely as an index of defensive reactivity. In human research, when pictures have been used as emotional stimuli, potentiation of the startle blink reflex in relation to neutral picture foregrounds tends to be maximal for depictions of directly threatening stimuli, such as aimed weapons and menacing assailants (Balaban & Taussig, 1994). Startle tends to be potentiated also for vicarious aversive images such as scenes of aggression or attack against others, but generally less robustly than for threat scenes (Bradley, Codispoti, Cuthbert, & Lang, 2001; Levenston, Patrick, Bradley, & Lang, 2000). In this regard, Bernat, Patrick, Benning, and Tellegen (2006) reported a positive association between the magnitude of startle potentiation and rated intensity of threat scenes that was not evident for victim scenes involving

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depictions of physical injury and attacks on others. Relatedly, Hamm, Cuthbert, Globisch, and Vaitl (1997) reported that animal and mutilation-fearful participants exhibited maximal potentiation of the startle response while viewing scenes related to their own phobias. Vrana, Constantine, and Westman (1992) reported similar results for participants with bird and dog phobias. These results suggest that aversive startle potentiation varies as a function of individual differences in fear of specific stimuli.

Individual Differences in Fear and Fearlessness: Relations with Aversive Startle Potentiation

Constructs pertaining to fearfulness are represented in various models of temperament and personality. One way in which fearfulness has been defined is as the level of negative emotion experienced in relation to unfamiliar or threatening objects or situations. Self-report fear scales of this kind include the Fearfulness subscale of the Emotionality-Activity-Sociability (EAS) Temperament Inventory (Buss & Plomin, 1984), the Fear Survey Schedule (FSS; Arrindell, Emmelkamp, & van der Ende, 1984), and the Harm Avoidance subscale of the Tridimensional Personality Questionnaire (TPQ; Cloninger, 1987). Fearfulness conceptualized in this way is distinct from, but correlated with, trait anxiousness (Buss & Plomin, 1984). The other interpretation of fearfulness is in terms of preference for safe but unstimulating activities over risky activities. Fear scales of this kind include the Thrill and Adventure Seeking subscale of the Sensation Seeking Scale (SSS; Zuckerman, 1979) and the Harm Avoidance subscale of the Multidimensional Personality Questionnaire (MPQ; Tellegen, in press). Fearfulness defined in this way is uncorrelated with trait anxiety (Tellegen & Waller, in press).

Cook and colleagues conducted a series of studies investigating the relationship between the startle reflex and individual differences in fearfulness as indexed by the FSS. Participants were selected on the basis of scores on the FSS to form extreme high and low fear groups. Cook, Hawk, Davis, and Stevenson (1991) measured startle responses during imaginal scenes designed to evoke fear, anger, sadness, joy, and pleasant relaxation. They found that high-fear participants showed greater startle potentiation during aversive scenes as compared to pleasant imaginal scenes, whereas low-fear participants showed no significant differences in startle magnitude across these imagery conditions. Cook, Davis, Hawk, Spence, and Gautier (1992) conducted a similar study in which participants viewed emotional and neutral pictures instead of imagining scenes. High-fear participants in this study showed larger startle blinks and reduced blink latencies while viewing aversive compared with neutral pictures, whereas low fear participants showed no reliable potentiation for aversive scenes. Likewise, Corr, Kumari, Wilson, Checkley, and Gray (1997) and Corr et al. (1995) reported that participants scoring high on the Harm Avoidance scale of the TPQ (TPQ-HA) showed greater potentiation of the startle response during unpleasant picture viewing compared with participants scoring low in TPQ-HA.

At the other extreme of the fear continuum, several investigators (e.g., Fowles, 1980; Hare, 1965; Lykken, 1995; Patrick, 1994) have posited that psychopathy involves a specific deficit in defensive (fear) reactivity, and empirical studies have demonstrated that certain features of psychopathy are associated with a lack of fear. The dominant clinical diagnostic instrument for assessing psychopathy, Hare's Psychopathy Checklist–Revised (PCL-R; Hare, 2003), includes two correlated factors (Hare, 2003; Harpur, Hare, & Hakstian, 1989).[1] PCL-R Factor 1 is marked by items reflecting the core affective-interpersonal features of psychopathy such as charm, glibness, manipulativeness/deceit, and lack of remorse, empathy, and deep emotion, whereas PCL-R Factor 2 reflects the impulsive, antisocial aspects of the syndrome. One widely used self-report instrument for assessing psychopathy, the Psychopathic Personality Inventory (PPI; Lilienfeld & Andrews, 1996), also has a parallel two-factor structure, with the first factor (PPI-I) reflecting tendencies toward stress immunity, social dominance, and fearlessness, and the second factor (PPI-II) reflecting propensities toward impulsivity, aggression, and antisocial deviance (Benning, Patrick, Hicks, Blonigen, & Krueger, 2003; Blonigen et al., 2005). Evidence indicates that it is the first factor of each instrument that is most associated with a lack of fear, in particular, lower scores on experiential measures of fear. PCL-R Factor 1 is correlated negatively with trait measures of fear and emotional distress, including the Fearfulness scale of the EAS Temperament Inventory (EAS-fear) and the FSS (Hicks & Patrick, 2006; Patrick, 1994), and positively with measures of social dominance (Harpur et al., 1989; Verona, Patrick, & Joiner, 2001). Paralleling this, PPI-I also shows robust negative associations with fear- and distress-related measures including the EAS-Fear scale and the FSS (Benning, Patrick, Blonigen, Hicks, & Iacono, 2005), and positive correlations with social dominance (Benning et al., 2003) as well as SSS Thrill and Adventure Seeking and, to a lesser extent, SSS Experience Seeking (Benning, Patrick, Blonigan, et al., 2005).

On the physiological side, Patrick, Bradley, and Lang (1993) demonstrated that incarcerated men diagnosed with psychopathy using the PCL-R displayed an abnormal startle pattern in which blink magnitude was diminished for both aversive and pleasant pictures in relation to neutral. These authors also reported that this pattern was specific to offenders with high scores on PCL-R Factor 1 as well as Factor 2, in contrast with offenders low on Factor 1, who displayed a normal linear pattern of blink modulation regardless of their scores on PCL-R Factor 2 (see also Vanman, Mejia, Dawson, Schell, & Raine, 2003). A similar pattern of diminished startle potentiation during aversive picture viewing was evident among incarcerated female psychopaths who scored low on a self-report anxiety scale (Sutton, Vitale, & Newman, 2002). Levenston et al. (2000) showed that this decrease in startle potentiation for psychopaths was evident for both direct threat and victim (mutilation, assault) scenes. More recently, Benning, Patrick, and Iacono (2005) investigated the relationship between scores on the two PPI factors and aversive startle potentiation in a sample of participants recruited from the general community. Results indicated that participants with high scores on PPI-I showed a pattern of inhibited startle for aversive pictures compared with neutral pictures, similar to incarcerated individuals high on PCL-R Factor 1. No such effect was evident for participants high on PPI-II. Findings from this study are of particular interest because of robust negative associations between PPI-I and measures of experiential fear, including the FSS and EAS-Fear scales (Benning, Patrick, Blonigen, et al., 2005). Justus and Finn (2007) also reported a lack of startle potentiation during viewing of unpleasant versus neutral pictures in men from the general community who scored high on PPI-I. In

[1]Alternative conceptualizations of the PCL-R have been proposed in recent work, focusing on three- (cf. Cooke & Michie, 2001) or four-factor (cf. Hare & Neumann, 2005) models.

contrast, this association was not evident among female participants in this study. However, both male and female participants in this study who scored high on the MPQ Harm Avoidance scale and the Welsh Anxiety Scale showed enhanced potentiation of startle during viewing of aversive pictures compared with neutral pictures.

Taken as a whole, findings reviewed in this section indicate that measures of fearfulness and measures of psychopathy show opposing relationships with startle potentiation to aversive stimuli. This pattern of results points to the possibility that fear-potentiated startle may operate as a physiological indicator of a broad fear/fearlessness continuum, with psychopathy/fearlessness at one end and extreme fearfulness at the other.

Evidence for a Common Factor Underlying Measures of Fear and Psychopathy/Fearlessness

Kramer, Bayevsky, Krueger, and Patrick (2008) undertook confirmatory factor analyses of self-report measures of dispositional fear together with measures of psychopathy/fearlessness to test the hypothesis that these two types of measures would operate as indicators of a common, bipolar dimension. Data for the following measures were collected from a large sample of adult men and women ($N = 2{,}572$) recruited from the community: the EAS–Fear scale, the FSS, the four subscales comprising the TPQ–HA scale, the three subscales that underlie PPI-I, and the Thrill and Adventure Seeking subscale of the SSS. Consistent with a priori hypotheses, the best fitting model of the data was one in which all of these scales loaded substantially on one broad, overarching factor (labeled *Trait Fear*), with some scales additionally loading on one of two subordinate factors (social assertiveness and stimulation seeking).

These results suggest that measures of dispositional fear and fearlessness are indicators of a common individual differences continuum. The low end of the continuum is marked by immunity to stressful events and situations, boldness in the interpersonal domain, and tendencies toward thrill seeking and enjoyment of risk. Individuals toward this end of the continuum are likely to exhibit emotional-interpersonal characteristics associated with psychopathy. The high end of the continuum is marked by intense responsiveness to threatening or unfamiliar situations or stimuli, discomfort in social situations, and avoidance of risk. Individuals at this end of the continuum are likely to exhibit symptoms of internalizing disorders, particularly phobic symptoms (Benning, Patrick, Blonigen, et al., 2005; Blonigen et al., 2005).

The Current Study

To examine relations between affect-modulated startle and scores on this broad dimension of fear and fearlessness, we administered the self-report scales demonstrated by Kramer et al. (2008) to be common indicators of this dimension (i.e., EAS-Fear, FSS, TPQ-HA subscales, PPI-I subscales, SSS-Thrill and Adventure Seeking). Scores on a principal component index of trait fear/fearlessness were extracted from these measures as a measure of this broad dimension. An affective-picture startle paradigm was utilized in which unpleasant, pleasant, and neutral scenes were included as stimuli. Given evidence that fear-potentiated startle effects may vary for differing picture contents such as threatening scenes or vicarious attack scenes, subsets of pictures representing different content categories were included in the picture-startle assessment.

The primary study hypothesis was that a positive monotonic association would be evident between magnitude of aversive startle potentiation and scores on the broad trait fear factor indexed by these varying fear- and psychopathy-related measures. A further prediction was that the association between trait fear scores and aversive startle potentiation would account for relations between specific measures of fear or psychopathy and aversive startle potentiation. Hypotheses for specific picture contents were somewhat more tentative. One possibility, based on findings from studies investigating the relationship between startle potentiation and specific phobias, was that the relationship between trait fear and startle potentiation would be greatest for pictures that were directly threatening to participants (e.g., scenes depicting aimed guns or attacking figures). An alternative hypothesis was that the association between individual differences in trait fear and startle potentiation would be stronger for vicarious attack (i.e., victim) scenes, as defensive reactivity to scenes of this type is less obligatory and, thus, potentially more variable across individuals. With regard to affective modulation of startle for pleasant pictures, only one study to date (Corr et al., 1995) has reported evidence of an association between dispositional fear (as indexed by TPQ-HA) and startle inhibition during pleasant picture viewing; other studies of fearfulness and psychopathy (e.g., Corr et al., 1997; Patrick et al., 1993) have not found differential modulatory effects for pleasant picture trials. Hence, no specific a priori hypotheses were advanced with regard to associations between trait fear scores and startle modulation for pleasant pictures as a whole or for specific pleasant contents.

Method

Participants

The base sample for the study consisted of 108 undergraduates recruited from psychology classes and through advertisements in the student newspaper at the University of Minnesota, who participated for course credit or $7.50/h as compensation. Among participants in this base sample, 8 failed to complete one or more of the study questionnaires and 12 others showed inadequate blink responding (see "Data Reduction" section). Data from the 100 participants (59 female, 41 male) who completed all study questionnaires were used in the principal components analysis of individual difference measures, described in the next section below. Results from the 88 participants (53 female, 35 male) with complete questionnaire scores as well as valid blink data were utilized in all other analyses. Participants were free of visual and hearing impairments, as assessed via a screening questionnaire.

Individual Differences Measures

Participants were administered a variety of fear- and fearlessness-related self-report questionnaires including the FSS (Arrindell et al., 1984), the EAS-Fear (Buss & Plomin, 1984), the four subscales of the TPQ-HA (Cloninger, 1987), the PPI-I (Lilienfeld, 1990; Lilienfeld & Andrews, 1996), and the Thrill and Adventure Seeking subscale of the SSS (Zuckerman, 1979).

The FSS required participants to rate their level of fear on a 5-point scale (ranging from *not at all* to *very much*) in relation to a variety of objects and situations, including open spaces, blood, animals, insects, public speaking, and aggression against others or self. Item scores were summed to yield a total fear score. Arrindell et al. (1984) reported that reliability (Cronbach's α) for total scores on the FSS, across a variety of subject samples including phobics, psychiatric inpatients and their partners, and university students, exceeded .92.

The EAS–Fear scale consists of four questions regarding tendencies to experience feelings of fear, panic, and insecurity. Participants answered each of these questions using a 4-point format (*true* [T], *somewhat true* [t], *somewhat false* [f], *false* [F]). Nærde, Røysamb, and Tambs (2004) reported test–retest correlations varying from .39 to .67 for individual items of this scale across a 2.5-year interval. Subjects were tested at three different points during this time period and test–retest correlations for the overall scale ranged from .62 to .68. Internal consistency as assessed by Cronbach's α across these varying time intervals ranged from .55 to .57.

The TPQ–HA scale includes four lower order scales consisting of questions pertaining to avoidance of harmful and unknown situations (HA1: anticipatory worry and pessimism vs. uninhibited optimism; HA2: Fear of uncertainty vs. Confidence; HA3: shyness with strangers vs. gregariousness; HA4: fatigability and asthenia vs. vigor). Participants answered these questions using the same 4-point response format (T, t, f, F). Cloninger, Przybeck, and Svrakic (1991) reported that alpha coefficients for the four subscales ranged from .45 to .73. Test–retest correlations across a 6-month interval varied from .59 to .75.

The PPI was developed to assess psychopathic traits in the general population. Its subscales load on two broad factors. Participants in the current study completed subscales associated with the first factor (PPI-I): Stress Immunity, Social Potency, and Fearlessness. Responses to each item were made using a 4-point scale (T, t, f, F). Reported internal consistencies for the PPI subscales range from .70 to .90; test–retest reliabilities range from .82 to .94 (Lilienfeld & Andrews, 1996; Poythress, Edens, & Lilienfeld 1998).

The Thrill and Adventure Seeking subscale of the SSS measures thrill-seeking tendencies in the general population. Each question is phrased in the form of two alternatives labeled A and B, one reflecting tolerance of risk/danger and the other aversion to risk. For each item, participants rated their preference for one or the other alternative along a 4-point scale: *definitely A*, *somewhat A*, *somewhat B*, and *definitely B*. A recent meta-analysis by Deditius-Island and Caruso (2002) reported a mean reliability coefficient (Cronbach's α) of .75 for this scale across 22 studies conducted from 1980 to 2001.

Consistent with the findings of Kramer et al. (2008), an exploratory principal components analysis of scores on these various individual difference measures revealed evidence of a dominant first factor (eigenvalue = 4.54, vs. 1.32 and 1.25 for subsidiary factors). Summary statistics for all questionnaire measures are presented in Table 1. Loadings for the various questionnaire scales on this dominant Trait Fear component are presented, in order of magnitude (highest to lowest), in Table 2. These loadings represent correlations between each individual scale and the extracted factor common to all scales. All scales loaded appreciably (.41 or higher) on the common fear factor. For purposes of analyses reported below, an omnibus Trait Fear index was calculated for each participant consisting of scores on this first component using the regression method, in which a component score was computed for each participant reflecting the sum of beta-weighted scores on the various fear and fearlessness measures.

Table 1. *Summary Statistics for Individual Fear and Fearlessness Scales*

Scale	Mean	Std. deviation	Range
High Fear indicators			
TPQ HA1–Anticipatory Worry	10.91	4.72	0–25
TPQ HA2–Fear of Uncertainty	14.49	5.99	4–27
TPQ HA3–Shyness with Strangers	12.33	6.82	0–29
TPQ HA4–Fatigability and Asthenia	10.05	5.14	1–27
EAS–Fear	11.08	5.63	0–25
Fear Survey Schedule–Total Score	9.49	4.56	1–25
Low Fear indicators			
PPI–Stress Immunity	15.56	5.02	4–28
PPI–Social Potency	16.39	4.40	5–25
PPI–Fearlessness	14.06	5.29	4–28
Sensation Seeking Scale–Thrill and Adventure Seeking	18.33	6.04	0–30

Stimulus Materials and Design

Each participant viewed a series of 90 pictures, consisting of 30 unpleasant, 30 pleasant, and 30 neutral scenes, selected from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention, 1999).[2] Pleasant pictures included erotic, nurturant (babies and small animals), and adventure scenes (10 of each); unpleasant pictures included threat (aimed guns and attacking animals), mutilation (injured bodies, limbs, faces), and victim scenes (also 10 of each). The 30 neutral scenes included a variety of scenes such as household objects, buildings, and neutral human faces. Stimuli within each picture category were selected to be gender matched in terms of mean IAPs normative ratings of valence and arousal. Because affective ratings for some IAPS pictures differ by gender, this resulted in some differences between the picture sets chosen for men and women: 44 of the 90 pictures comprising the stimulus set were the same for men and women, with the remainder being different. Mean valence and arousal ratings (respectively) for the three picture valence categories across the sample as a whole were: pleasant: 7.58, 6.22; neutral: 5.02, 2.82; and unpleasant: 2.48, 6.24. Mean valence and arousal ratings for specific affective picture contents across the sample as a whole were: erotic: 7.41, 6.84; nurturant: 7.80, 4.99; adventure: 7.52, 6.82; threat: 2.96, 5.90; mutilation: 2.07, 6.57; and victim: 2.42, 6.26.

[2]The IAPS identification numbers for the 90 pictures used in this study are listed below. Pictures that were presented to both men and women are underlined. Pictures that were presented without noise probe stimuli are italicized. Pleasant: erotic (men): *2530*, 4210, 4232, 4250, 4652, 4659, 4607, 4664, 4670, 4180; erotic (women): *2530*, 4538, 4550, 4572, 4608, 4656, 4660, 4677, 4687, 4689; nurturant (men): 1440, 1463, 1721, 1722, *1750*, 2071, 2150, 2160, 2311, 2340; nurturant (women): 1463, 1710, *1750*, 2040, 2050, 2058, 2071, 2150, 2160, 2165; adventure (men): 5470, 5621, 8030, *8050*, 8080, 8170, 8180, 8185, 8370, 8400; adventure (women): 5621, 5629, 8030, *8050*, 8034, 8080, 8185, 8200, 8370, 8490; neutral (men): 2210, 2214, *2215*, 2372, 2393, 2495, 2499, 2870, 2890, 5731, 7000, 7002, 7009, 7010, 7020, 7034, 7038, 7041, *7050*, 7090, 7100, 7130, 7180, 7233, 7490, 7491, 7500, *7510*, 7595, 9070; neutral (women): 2190, *2215*, 2393, 2480, 2495, 2499, 2890, 2516, 2570, 4605, 6150, 7000, 7004, 7006, 7010, 7020, 7041, *7050*, 7080, 7100, 7130, 7140, 7161, 7175, 7180, 7217, 7491, 7500, *7510*, 7590; unpleasant: threat (men): *1220*, 1525, 6210, 6241, 6242, 6250, 6300, 6370, 6510, 6830; threat (women): *1220*, 1525, 6190, 6213, 6241, 6242, 6300, 6370, 6610, 6800; mutilation (men): 3010, 3053, 3060, *3064*, 3069, 3071, 3080, 3102, 3130, 3400; mutilation (women): 2352, 3051, 3061, *3064*, 3071, 3080, 3150, 3250, 3400, 9490; victim (men): 3180, *3280*, 3350, 3500, 3530, 3550, 6313, 6350, 6530, 9040; victim (women): 3022, *3280*, 3500, 3550, 6211, 6312, 6530, 6550, 6561, 6831.

Table 2. *Loadings of Individual Fear and Fearlessness Scales on the First (Trait Fear) Component Extracted from a Principal Components Analysis of All Scales*

Scale	Trait Fear component loading
High Fear indicators	
TPQ HA1–Anticipatory Worry	.74
TPQ HA2–Fear of Uncertainty	.82
TPQ HA3–Shyness with Strangers	.65
TPQ HA4–Fatigability and Asthenia	.61
EAS–Fear	.75
Fear Survey Schedule–Total Score	.60
Low Fear indicators	
PPI–Stress Immunity	−.78
PPI–Social Potency	−.67
PPI–Fearlessness	−.63
Sensation Seeking Scale–Thrill and Adventure Seeking	−.41

During 81 of the 90 picture stimuli, noise probes (50 ms, 105 dB, 10 μs rise time) were presented at varying points during the 6-s viewing interval to elicit startle blink responses. The probes occurred 3, 4, or 5 s after picture onset. For 6 of the remaining 9 pictures, startle probes were delivered during the intertrial interval at either 1, 1.5, or 2 s following picture offset. The remaining 3 trials did not include any startle probe at all. Preceding the main picture series in which responses were recorded, participants completed a practice series of three probed picture trials (IAPS numbers 4650, 7080, and 9252) in order to familiarize them with the task stimuli. This practice series was separated from the main series by an interval of approximately 1 min, during which time final instructions for the task were provided.

Nine slide presentation orders were used for each gender subgroup. Within and between orders, pictures and startle probes were counterbalanced such that all valence categories (pleasant, neutral, unpleasant) and affective contents (erotic, nurturant, adventure; threat, mutilation, victim) were represented equally across orders at each serial position, with the following constraints: no more than two pictures of the same valence occurred consecutively within any stimulus order; pictures of the same content category never appeared consecutively; and across orders, pictures were rotated so as to serve in both probed and unprobed trials.

Stimulus Delivery and Physiological Measures

Participants sat in a padded recliner during the experiment at a distance of 100 cm from a 21-in. computer monitor on which picture stimuli were displayed. Blink responses to noise probes were recorded from a pair of Med Associates 0.25 cm Ag–AgCl electrodes filled with electrolyte paste and positioned over the orbicularis oculi muscle under the left eye. Data collection was performed using two IBM compatible computers, one running E-Prime software (MEL software, Inc.) for stimulus delivery and the other running Neuroscan Acquire software for physiological data acquisition. Blink EMG responses were recorded at a sampling rate of 1000 Hz using a Neuroscan SynAmps amplifier, with a 200-Hz low-pass and 0.05 Hz high-pass analog filter applied before digitization to prevent aliasing (Blumenthal et al., 2005). Data were then digitally high-pass filtered at 10 Hz to remove artifacts due to movement (van Boxtel, Boelhouwer, & Bos, 1998). Lastly, the signals were rectified and integrated using a digital single-pole recursive filter (implemented using Matlab software; Mathworks, Inc.) to simulate a Coulbourn contour-following filter with a 30-ms time constant.

Procedure

The data from this picture-viewing task were collected as part of a larger experimental protocol. Prior to commencement of testing, participants provided written informed consent and then completed a biographical form that screened for physical ailments, medication use, and visual and auditory impairments, along with a set of questionnaires that included the various fear- and fearlessness-related measures described above.

After this, electrodes were attached for physiological measurement and participants were advised they would be viewing a series of emotional pictures, each for its entire time of presentation. They were also advised that they would hear brief noises at times through earphones, which they could simply disregard. Each of the 90 picture stimuli was presented for a period of 6 s, followed by an intertrial interval of 12 s.

Data Reduction

The response to the first noise probe delivered in the task was discarded for each participant, as this initial response was disproportionately large compared with responses to subsequent probes (cf. Patrick et al., 1993). To quantify the magnitude of startle blink responses to all other probes, a scoring algorithm was implemented using Matlab in which the peak of the startle response was defined as the highest point occurring between 30 and 120 ms following noise probe onset, relative to the median activity evident during the 50-ms period preceding the probe. Following this, all trials were visually inspected by two independent blind evaluators to identify trials with unstable baselines and zero-amplitude responses. Trials identified as unstable included those on which blink onset occurred earlier than 20 ms, trials in which a startle response overlapped with a preceding spontaneous eyeblink, and trials involving a highly variable preprobe baseline. Zero amplitude response trials were defined as trials in which no discernible blink response occurred within the 30–120-ms peak window. Trials that either evaluator set to missing (in the case of unstable baselines) or zero (in the case of no discernible blink response) were flagged.

Using these criteria for evaluation of individual trials, trials with unstable baselines and trials with zero responses were tallied for each participant. Participants with $\geq$ 30% of trials (i.e., 27 or more) classified as either missing or zero response trials according to both evaluators were identified as candidates for exclusion. As an additional check prior to exclusion, a third blind evaluator independently reevaluated the data for all participants who met this aggregate criterion. Combining results across all evaluators, approximately 8.6% of trials were set to missing due to unstable baselines and 5.3% were scored as zero responses. Trials that all three evaluators flagged as either missing or zero-response trials were flagged, and participants with $\geq$ 30% of trials flagged in this manner (n = 12) were excluded entirely from the analysis. This resulted in a total of 88 participants for the data analyses reported below.

Following the identification of valid blink response peaks using these procedures, startle blink magnitude was computed as the difference between peak orbicularis level and the median level during a 50-ms prestimulus baseline. To establish a common metric for all participants in the evaluation of relations between startle reflex modulation and trait fear, raw startle magnitude values were converted to T score units by standardizing raw values across trials within each participant (cf. Bradley et al., 2001; Levenston et al., 2000) as follows: z score value = (raw magnitude value $- M_{\text{all raw values}})/SD_{\text{all raw values}}$; T score value = ($z$ score value $\times$ 10)+50. This resulted in standardized blink magnitude scores with a mean of 50 and a standard deviation of 10 for each participant.

Data Analysis

Two sets of analyses were conducted. The first set examined startle modulation effects in the sample as a whole as a function of picture valence and for specific pleasant and unpleasant picture contents. For the analysis of picture valence, we utilized a multivariate analysis approach in which picture valence (pleasant, neutral, and unpleasant) was included as a within-subjects factor. The omnibus effect of picture valence is reported in terms of a multivariate F statistic. In addition, planned univariate linear and quadratic contrasts across the levels of valence were conducted to elucidate the omnibus multivariate effect. Modulation effects for specific content categories were examined by comparing average blink magnitude for each affective picture content against magnitude for neutral pictures and by comparing differing pleasant and unpleasant contents with one another.

A second set of analyses examined correlations between trait fear scores (omnibus component and individual scale scores) and startle modulation for pleasant and unpleasant picture categories overall, as well as for specific pleasant and unpleasant picture contents. Associations were examined for the sample as a whole and for male and female subgroups separately. Because our primary focus was on predictive relations between fear scores and modulation effects for emotional pictures, affect minus neutral difference scores (pleasant–neutral, unpleasant–neutral, erotic–neutral, adventure–neutral, etc.) served as the criterion variables in these correlational analyses. For each set of modulation scores, outlying score values (i.e., scores falling more than 2 *SD*s above or below the sample mean) were winsorized (reined in) to a value corresponding to 2 *SDs* to ensure our results were not disproportionately influenced by individuals exhibiting extreme modulation effects. For pleasant and unpleasant modulation scores, data for 4 subjects had to be winsorized, and for threat modulation scores only 2 subjects had to be reined in. In all cases, this procedure attenuated observed associations only slightly.

Because specific directional relationships were predicted between fear questionnaire measures and magnitude of aversive startle potentiation (i.e., positive for measures of fear, negative for measures of fearlessness), one-tailed significance values are reported for these effects along with two-tailed significance values. Two-tailed significance values are reported for all other effects.

Results

Overall Sample: Startle Modulation Effects for Picture Valence Categories and Specific Picture Contents

Replicating extensive prior research (cf. Lang et al., 1997), analysis of standardized blink magnitude scores revealed a significant main effect of picture valence, multivariate $F(2,86) = 24.65$, $p < .01$, with blink magnitudes larger during unpleasant versus pleasant pictures, linear $F(1,87) = 49.41$, $p < .01$, and intermediate during neutral pictures, quadratic $F(1,87) = 1.20$, $p > .05$ (see Figure 1). In addition, paired samples t-tests revealed that blink magnitude differed significantly during both pleasant (inhibition) and unpleasant pictures (potentiation) in comparison to neutral pictures: (Pleasant–Neutral) $t(87) = -3.32$, $p < .01$; (Unpleasant–Neutral) $t(87) = 4.29$, $p < .01$. For unpleasant picture contents, paired samples t-tests revealed that all three contents showed significant blink magnitude potentiation relative to neutral pictures: threat, mutilation, and victim pictures, ts(87) = 2.60, 4.28, and 2.20, respectively, all ps < .05 (see Table 3). Direct comparisons of means for specific contents revealed significantly greater magnitude for mutilation pictures than for victim pictures, $t(87) = 2.34$, $p < .05$, but no difference for mutilation pictures compared with threat pictures, $t(87) = 1.91$, $p > .05$, and no difference for victim pictures compared with threat pictures, $t(87) = -.36$. For pleasant picture contents, erotic pictures showed significant blink magnitude inhibition relative to neutral pictures, $t(87) = -8.28$, $p < .01$, whereas nurturant and adventure scenes did not, ts(87) = .73 and −.30, ps > .05, respectively (see Table 3). Direct comparisons of these contents revealed that erotic pictures differed significantly from both adventure pictures and nurturant pictures, ts(87) = −6.46 and −6.80, respectively, ps < .01, whereas adventure and nurturant pictures did not differ significantly from one another, $t(87) = -.88$.

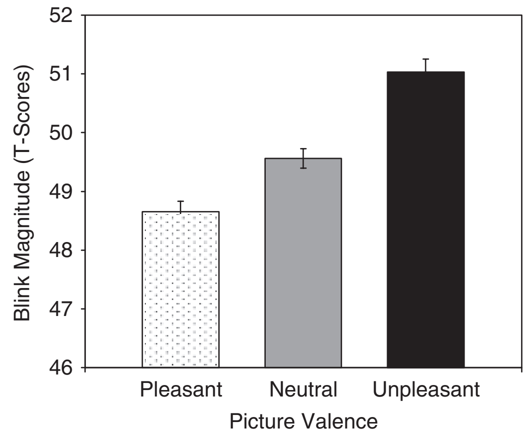

Figure 1. Mean magnitude of blink response to startle probes during viewing of pleasant, neutral, and unpleasant pictures in the test sample as a whole ($N = 88$).

Associations between Fear/Fearlessness Measures and Startle Modulation Effects

Modulation for picture valence categories. Because the focus of predictions for measures of fear and fearlessness was on vari-

Table 3. *Startle Blink Magnitude Ms (SDs) and Modulation Difference Scores, in Standard T-Score Units, for Specific Affective Picture Contents in the Test Sample as a Whole (N = 88)*

Picture content	Blink Magnitude M (SD)	(Content–Neutral) difference
Erotic	46.64 (2.87)	−2.92*
Nurturant	49.87 (3.27)	0.31
Adventure	49.45 (2.91)	−.11
Threat	50.73 (3.61)	1.17*
Mutilation	51.84 (4.14)	2.28*
Victim	50.53 (3.34)	0.97*

*$p < .05$ (two-tailed).

Table 4. *Correlations of Trait Fear Component Scores and Individual Fear/Fearlessness Scales with Startle Modulation Scores for Pleasant and Unpleasant Pictures, within the Overall Test Sample (N = 88)*

Measure	*r* with (Unpleasant–Neutral) difference Overall	*r* with (Pleasant–Neutral) difference Overall
Trait Fear Component Score	.18$^+$	− .12
High Fear indicators		
TPQ HA 1–Anticipatory Worry	.20$^+$	− .11
TPQ HA 2–Fear of Uncertainty	.13	− .15
TPQ HA 3–Shyness	.16	.01
TPQ HA 4–Fatigability	.19$^+$	− .10
EAS–Fear	.17	.02
Fear Survey Schedule–Total Score	.09	− .06
Low Fear indicators		
PPI I–Stress Immunity	− .08	.21*
PPI I–Social Potency	− .15	− .01
PPI I–Fearlessness	− .01	.08
SSS–Thrill and Adventure Seeking	− .02	.16

*$p < .05$ (two-tailed).
$^+p < .05$ (one-tailed).

ations in affective modulation of the startle response, modulation scores for pleasant and unpleasant picture categories were computed as the mean difference between blink magnitude for pictures of each type minus magnitude for neutral pictures. All statistics from this point on utilize these affective modulation scores.

Table 4 shows correlations between fear/fearlessness measures and unpleasant versus neutral and pleasant versus neutral blink modulation scores in the sample as a whole. Although weak, a reliable association in the predicted direction was found between omnibus Trait Fear scores and startle modulation for unpleasant pictures, $r = .18$, $p < .05$ one-tailed, reflecting greater potentiation for individuals higher in fear. Examining gender groups separately, this positive association was significant for men, but not women, *r*s = .36 and .11, respectively, *p*s = .03 and .45. Additionally, within the sample as a whole and among men in particular, correlations for individual fear/fearlessness measures were uniformly in expected directions. Questionnaires reflecting fearfulness showed positive correlations with startle potentiation for unpleasant pictures whereas questionnaires reflecting fearlessness showed mostly negative correlations. Effects for women were less consistent. Modulation scores for pleasant pictures as a whole showed no reliable association with fear measures in the overall sample or in either gender subgroup.

Modulation for specific picture contents. Startle modulation scores for each affective content category (erotic, nurturant, adventure, threat, mutilation, victim) were computed as the difference between average blink magnitude during pictures of that content minus average magnitude for neutral pictures. As we were concerned primarily with relations between fear scores and degree of affect modulation, all statistical tests below utilize these modulation scores.

For threat pictures specifically, a robust positive association was observed between Trait Fear component scores and startle potentiation scores in the sample as a whole (see Figure 2). As shown in Table 5, this association was also robust in both male

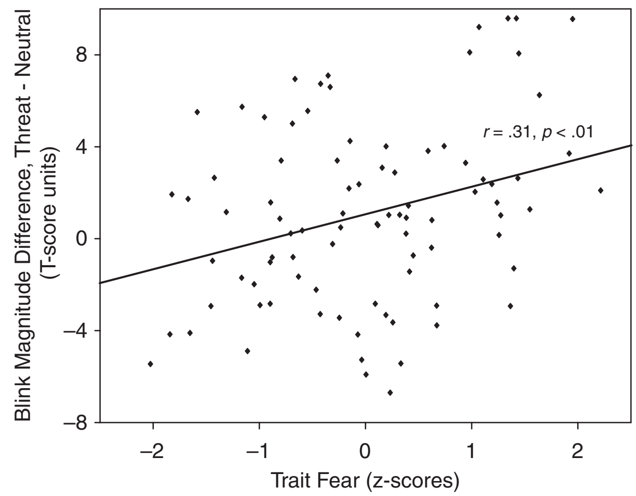

Figure 2. Scatterplot depicting the relationship, within the test sample as a whole ($N = 88$), between Trait Fear component scores and mean startle modulation scores for threat pictures (i.e., average blink magnitude for threat minus average magnitude for neutral pictures).

and female participant subgroups. Table 5 also depicts correlations between potentiation scores for threat pictures and individual fear/fearlessness measures in the sample as a whole and in men and women separately. It can be seen that associations for individual fear indicators are lower in magnitude but generally in expected directions, with high fear indicators showing positive correlations with threat potentiation and low fear indicators showing negative correlations. This consistency is evident both in the sample as a whole and in the two gender subgroups.

We hypothesized that the omnibus trait fear variable representing the construct that these varying indicators of fear and fearlessness have in common would account for observed relations between individual indicators and aversive startle potentiation. As shown in Table 5, 8 of the 10 indicator scales for the entire sample showed significant or near significant associations

Table 5. *Correlations of Trait Fear Component Scores and Individual Fear/Fearlessness Scales with Startle Modulation Scores for Threat Pictures Specifically, within the Overall Test Sample (N = 88) and for Women and Men Separately (ns = 53 and 35)*

Measure	*r* with (Threat–Neutral) difference		
	Overall	Women	Men
Trait Fear Composite Score	.31*	.31*	.28$^+$
High Fear indicators			
TPQ HA 1–Anticipatory Worry	.19$^+$	.22	.12
HA 2–Fear of Uncertainty	.23*	.23	.21
TPQ HA 3–Shyness	.24*	.36*	.09
TPQ HA 4–Fatigability	.19$^+$	.26$^+$	.05
EAS–Fear	.23*	.15	.31$^+$
Fear Survey Schedule–Total Score	.08	− .03	.21
Low Fear indicators			
PPI I–Stress Immunity	− .25*	− .15	− .37*
PPI I–Social Potency	− .27*	− .37*	− .15
PPI I–Fearlessness	− .18$^+$	− .12	− .21
SSS–Thrill and Adventure Seeking	− .17	− .14	− .19

*$p < .05$ (two-tailed).
$^+p < .05$ (one-tailed).

in predicted directions with blink potentiation for threat pictures. We used hierarchical regression analyses to evaluate the mediating role of trait fear in associations for these eight scales. Scores on a specific scale were entered as a predictor in the first step of each analysis, followed by trait fear composite scores in the second step. For each indicator scale, the significant bivariate relationship with startle potentiation for threat pictures evident in the first step of the analysis was reduced to nonsignificance in the second step, after the trait fear composite was entered as a predictor. In no case did the unique variance associated with a particular scale contribute significantly to its association with startle potentiation independently of trait fear scores. These results indicate that observed relations between individual fear/fearlessness scales and aversive startle potentiation reflect the common construct tapped by these varying scales (i.e., trait fear).

Aside from threat pictures, no other specific picture contents yielded significant correlations between startle modulation scores and fear/fearlessness measures (omnibus fear or individual scale scores) in the sample as a whole. However, gender-specific associations were found for two other picture contents. Men alone showed significant correlations between degree of startle potentiation for *mutilation* scenes and measures of fear/fearfulness, with the direction of associations indicating greater potentiation for men higher in fear: For omnibus trait fear scores, $r = .36$, $p < .05$ two-tailed; for individual scales, correlations were positive for all high fear indicators (rs = .25 to .43) and negative for three of four low fear indicators (rs = $-.23$ to .06). Corresponding correlations for women were all small and nonsignificant (rs = $-.07$ to .14). On the other hand, women alone showed significant correlations between degree of startle inhibition for *erotic* scenes and measures of fear/fearfulness, with the direction of correlations indicating greater inhibition of startle during these scenes among women higher in fear: For omnibus trait fear scores, $r = -.31$, $p < .05$ two-tailed; for individual scales, correlations were negative for all six high fear indicators (rs = $-.30$ to $-.03$) and positive for all four low fear indicators (rs = .18 to .31). Corresponding correlations for men were all nonsignificant and generally opposite in direction to those for women (i.e., positive for five of six high fear indicators, rs = $-.15$ to .20, and negative for three of four low fear indicators, rs = $-.19$ to .09).

Discussion

This study investigated the relationship between aversive potentiation of the startle reflex and a bipolar trait dimension of fearlessness/fearfulness that is posited to play a role in both normal personality and psychopathological syndromes involving excessive or deficient emotional reactivity. Results for the current sample as a whole replicated the basic linear startle effect (i.e., unpleasant > neutral > pleasant) reported in numerous prior studies, beginning with Vrana, Spence, and Lang (1988). Also consistent with prior research, the three unpleasant picture contents we examined each yielded significant startle potentiation compared with neutral pictures, and among pleasant contents only erotic pictures produced significant startle inhibition (cf. Bradley et al., 2001). Somewhat unexpectedly, startle response magnitude for threat pictures did not exceed magnitude for other unpleasant picture contents (mutilation, victim) in the current study sample, although magnitude for mutilation scenes exceeded that for victim scenes. This might have to do with the specific selection of scenes of each type used in this study. Nevertheless, as discussed below, associations between aversive potentiation and individual difference measures were strongest for scenes of aimed weapons and attackers involving direct threat to the viewer.

Trait Fear and Affective Startle Modulation

Consistent with prior research findings, the current study found positive and negative correlations, respectively, between the degree of enhanced startle reactivity during aversive versus neutral pictures (i.e., fear-potentiated startle) and questionnaire measures reflecting fear and fearlessness/psychopathy (cf. Cook, 1999; Patrick & Bernat, in press). These correlations were most robust for directly threatening scenes entailing depictions of aimed weapons, menacing assailants, and attacking animals. Furthermore, the individual differences variable that predicted startle potentiation to threatening pictures most consistently across participants as a whole and within the two gender subgroups was the omnibus Trait Fear index, and hierarchical regression analyses revealed that scores on this dimensional measure mediated relations between individual fear/fearlessness scales and threat potentiation. These results suggest that the personality construct embodied in the Trait Fear component measure may account for previously reported associations (positive and negative, respectively) between aversive startle potentiation and self-report indices of fearfulness and psychopathy.

The finding that participants higher in fearfulness startled more vigorously during threat pictures in particular is reminiscent of findings from studies of individuals with specific phobias. Studies of this kind have consistently reported enhanced startle potentiation among phobic individuals, especially in relation to visual depictions of their feared objects (e.g., De Jong, Merckelbach, & Arntz, 1991; Hamm et al., 1997; Vrana et al., 1992). This effect has been interpreted as reflecting enhanced sensitivity among phobic individuals in subcortical defensive circuits (including the amygdala) to specific fear-related stimuli (Globisch, Hamm, Esteves, & Ohman, 1999). The fact that enhanced startle potentiation occurred for high trait fear individuals in relation to threatening scenes such as aimed guns, pointed knives, and attacking figures suggests enhanced defense system activation —perhaps at the level of the amygdala—to immediate representations of danger in such individuals. This interpretation is consistent with neuroscientific conceptualizations of the amygdala as playing a specific role in cue-specific fear (e.g., Davis, 2000) and also with neuroimaging data indicating that individuals high in fear show enhanced amygdala reactivity to fear cues (e.g., Most, Chun, Johnson, & Kiehl, 2006; but see Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005; Wendt, Lotze, Weike, Hosten, & Hamm, 2008).

On the other hand, the finding that participants low in fear showed deficient startle potentiation during threat picture viewing coincides with findings from studies of incarcerated individuals diagnosed with psychopathy. Studies of this kind have consistently reported a lack of normal startle potentiation and in some instances inhibition of startle responding among psychopathic individuals during their viewing of aversive pictures including threat scenes (cf. Patrick & Bernat, in press). Notably, this effect has been linked particularly to the emotional-interpersonal (Factor 1) features of psychopathy, which show negative relations with trait measures of fear and negative affectivity (Hicks & Patrick, 2006). It is these features that Cleckley (1941) highlighted in his classic clinical description of the syndrome, which he viewed as arising from a core deficit in emotional sensitivity. The deficiency in startle potentiation among individuals exhibiting the emotional-interpersonal features of psychopathy has been interpreted as reflecting a weakness in basic defensive reactivity, perhaps at the level of the amygdala (Blair, 2006; Patrick, 2007). This interpretation is consistent with neuroimaging data indicating reduced amygdala reactivity to emotional stimuli in individuals high in clinical features of psychopathy (Flor, Birbaumer, Hermann, Ziegler, & Patrick, 2002) and among individuals high on the component of the PPI that reflects dominance, stress immunity, and fearlessness (PPI-I; Gordon, Baird, & End, 2004).

In addition to effects for direct threat scenes, associations with measures of fear and fearlessness were found for two other affective picture contents, but in both cases these effects were gender-specific. Men alone showed an association between level of fearfulness and degree of startle potentiation for mutilation versus neutral scenes. On the other hand, women alone showed an association between trait fear and startle inhibition for erotic pictures. In this case, the direction of association was such that women higher in fear showed enhanced inhibition during viewing of erotic pictures. Because these effects were unpredicted as well as gender specific, interpretations are necessarily speculative and it will be important to replicate such findings in future work before attempting to explain them.

Implications for Psychophysiological Investigation of Individual Differences

This study has a number of important implications for research on the neurobiological bases of individual differences. One is that the bipolar dimension of trait fear identified in the current study is potentially a valuable target construct in the study of physiological response differences related to personality and psychopathology. Notably, this construct is not associated narrowly with one specific trait in the domain of self-report; instead, it represents a nexus of varying self-report personality traits known to be associated with variations in defensive reactivity as indexed by aversive startle potentiation. Its indicators include measures of dominance (PPI-Social Potency, TPQ-HA Shyness), negative affectivity (TPQ-HA Anticipatory Worry, PPI-Stress Immunity), and sensation seeking (SSS–Thrill and Adventure Seeking) along with scales ostensibly measuring fear and fearlessness.

A related point is that the current findings provide support for the predictive power of multivariate phenotypes (cf. Iacono, 1998). That is, associations between a target personality construct and a relevant biological variable may prove to be more robust for an omnibus index based on multiple phenotypic indicators than for individual measures. In the current study, the omnibus trait fear index showed more consistent associations with startle potentiation in the sample as a whole and across gender subgroups than any of its individual self-report indicators. Our proposed explanation is that the trait fear index provides a purer, more reliable measure of the underlying construct, tapped by these varying scales, that relates to variations in defensive reactivity as indexed by startle potentiation.

What underlying construct does this omnibus trait fear measure reflect? Our working hypothesis is that scores on this dimensional measure reflect variations in the tendency to experience fear in relation to threatening objects/stimuli across varying spheres of activity. That is, it indexes individual differences in cue-specific fear reactivity, as opposed to constructs such as neuroticism or anxiousness, which reflect "free-floating" or nonspecific negative affect. This construct is tapped to some extent by each of the indicators used in the current study, but it is not strictly equivalent to any of them. Rather, trait fear reflects the common core of these varying measures of fear and fearlessness—and, in particular, the component that predicts variations in aversive startle potentiation.

In the animal neuroscience literature, Davis and colleagues (see Davis, 1989, 1992; Davis, Falls, Campeau, & Kim, 1993; Davis & Shi, 1999) presented evidence that fear-potentiated startle is mediated by the central nucleus of the amygdala, considered to be the core of the cue-specific fear system. Their work demonstrated that the central nucleus of the amygdala (ceA) projects down to the nucleus reticularis pontis caudalis (nRPC), the component of the startle circuit that lies between the sensory input component and the motor output component. Lesions along the pathway from the ceA to the nRPC have been shown to eliminate fear-potentiated startle (Lee, Lopez, Meloni, & Davis, 1996). This work indicates that the startle reflex is enhanced during exposure to aversive cues because such cues prime the defensive (amygdala) system, which projects to the startle circuit. Lang et al. (1997) proposed that a similar defensive-priming mechanism accounts for aversive startle potentiation in humans. In turn, we posit that the dimension of trait fear reflects individual differences in emotional reactivity at the level of self-report that are associated at a more basic biological level with variations in the sensitivity of this cue-specific fear system.

A further implication of the current study is that particular categories of emotional pictures may be more sensitive to individual differences than others. In the current study, the most consistent associations with trait fear were found for threat pictures. Our interpretation is that among unselected participants, pictures of this type most directly activate the cue-specific fear system that is the basis for individual differences in trait fear. Depictions of other negative stimuli or events such as mutilated bodies or vicarious attack scenes may evoke mixed reactions that include elements of other emotions besides fear (e.g., disgust, sympathy, anger, curiosity), in contrast with the purer defensive reactions evoked by threat scenes.

In summary, the findings of the current study establish a bridge between prior published research on individual differences in startle modulation associated with fearfulness on one hand and psychopathy on the other. Our findings indicate that an underlying bipolar dimension encompassing variations in fear and fearlessness accounts for associations reported in these two domains. Further investigation of the physiological correlates and underpinnings of this trait dimension should contribute importantly to an understanding of psychological disorders marked by excessive fear as well as to an understanding of the classic syndrome of psychopathy.

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