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Sensation seeking and startle modulation by physically threatening images

Shmuel Lissek [a,*], Alice Schade Powers [b]

[a] National Institute of Mental Health, Mood and Anxiety Disorders Program, 15K North Drive, Bldg 15k, MSC 2670, Bethesda, MD 20892-2670, USA
[b] Department of Psychology, St. John's University, 8000 Utopia Parkway, Jamaica, NY 11439, USA

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Abstract

The potential moderating effect of sensation seeking on anxious reactivity to threatening experiences was assessed using the affective modulation of startle-blink paradigm. Startle blinks, as measured by electromyographic (EMG) activity in response to loud (100 dB) white-noise stimuli, were elicited during the presentation of positive, neutral, and threatening visual images. Unlike participants low in sensation seeking who showed blink potentiation during threatening versus neutral images, participants high in sensation seeking showed equal magnitudes of startle to neutral and threatening images. The results suggest that individuals high compared with low on sensation seeking are less anxiously reactive to physically threatening visual stimuli. No attenuation in startle magnitude was elicited by positive images among low or high sensation seekers suggesting that the positive images employed in the current study were not arousing enough to activate the appetitive arousal system.

Keywords: Sensation seeking; Anxious reactivity; Resilience; Affective modulation of startle; Psychophysiology

1. Introduction

Sensation seeking is a dimension of personality referring to both an individual's need for sensory stimulation and the level of risk taken in an effort to satisfy the need

* Corresponding author. Tel.: +1-301-402-7219; fax: +1-301-402-6353.
E-mail address: lisseks@intra.nimh.nih.gov (S. Lissek).

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for such stimulation (Zuckerman, 1994). It has been found to buffer individuals from stress associated with physically threatening events such as sports-related injury (Smith et al., 1992) and skydiving (Breivik et al., 1998). Additionally, sensation seeking has been found to play a stress-buffering role for individuals enduring military combat. For example, Solomon et al. (1995) found lower rates of posttraumatic stress disorder (PTSD) and less severe psychiatric symptomatology among high relative to low sensation-seeking Israeli POWs of the Yom Kippur War (Solomon et al., 1995). Similarly, in a reanalysis requested by the current authors, Orr et al. (1990) found a significant negative correlation (−0.32) between the thrill and adventure seeking subscale (TAS) of the sensation seeking scale (SSS) and trait anxiety among Vietnam veterans (S.P. Orr, personal communication, May 11, 1999) indicating lower levels of post-war trait anxiety among those higher on the TAS subscale.

The factors responsible for the potential stress-buffering function of sensation seeking remain relatively unstudied. One possibility is that high sensation seekers are less anxiously reactive to physical threat, which in turn facilitates resilient adaptation. This idea is supported by several studies demonstrating inverse relations between sensation seeking and self-reported anxious reactivity to physically risky activities and situations (Blankstein, 1975; Franken et al., 1992; Segal, 1973; Zuckerman, 1979). This idea is also consistent with findings that high relative to low sensation seekers are less responsive to appeals for safe sex and drug prevention that include threatening health information for persuasive purposes (Schoenbachler and Whittler, 1996; Witte and Morrison, 1995). The above studies provide correlational support for an inverse relationship between sensation seeking and anxious reactivity to threat. The current study aims to investigate experimentally this relationship using the affective modulation of startle paradigm (Vrana et al., 1988).

Affective modulation of startle refers to the tendency for negative affective states (e.g. anxiety and disgust) and positive affective states (e.g. joy and lust) to potentiate and attenuate the startle response, respectively. Such modulation of the startle blink has been obtained by presenting positive, neutral, or negative pictures from a standardized collection of images known as the International Affective Picture System (Lang et al., 1988) to subjects just prior to the onset of an auditory startle stimulus (for a review, see Bradley et al., 1999). Given that startle is augmented best by physically threatening IAPS images (Balaban and Taussig, 1994), potentiated-startle may be a particularly sensitive index of emotional reactivity to threat, making affective startle modulation an ideal paradigm for the research question at hand.

The potentiation elicited by negatively-valenced stimuli has been understood as a fear reaction and has, therefore, been referred to as fear-potentiated startle (e.g. Grillon et al., 1993; Grillon and Ameli, 2001). Evidence for this interpretation comes from studies showing that potentiation of startle resulting from negative stimuli in humans is attenuated by diazepam, an anxiolytic drug (Bitsios et al., 1999; Patrick et al., 1996). Similarly in animal studies, rats administered drugs that decrease anxiety in humans (e.g. diazepam and flurazepam) display reduced levels of fear-potentiated startle, and rats administered drugs that increase anxiety in humans (e.g. piperoxan and yohimbine) show elevated levels of fear-potentiated startle (Davis, 1979; Davis et al., 1979). Finally, fear-potentiated startle has been blocked following lesions of amygdala-based "fear" circuits in both animal (Hitchcock and Davis, 1986) and human studies (Angrilli et al., 1996). Due to the aforementioned evidence, potentiation of startle by threatening IAPS images in low and high sensation seekers is conceptualized as a measure of anxious reactivity to threat.

Because of findings pointing to the importance of the TAS for determining emotional and perceptual reactions to threatening stimuli (Franken et al., 1992; Orr et al., 1990) and because anxious reactivity to hypothetical situations of physical harm is negatively related to the TAS subscale of the SSS more than to any other of its subscales (Blankstein, 1975; Zuckerman, 1979), we were particularly interested in comparing startle potentiation to threatening images across high and low sensation seekers with extreme high and low TAS scores, respectively. In addition to presenting neutral and threateningly valenced slides, we also presented positive slides, as is typically done in studies of affective modulation of startle (Bradley et al., 1990).

In addition to studying the effects of sensation seeking on the fear-potentiating aspect of the startle blink, the current experiment investigated the relationship between sensation seeking and both startle-blink thresholds (i.e. lowest intensity at which startle, unaccompanied by affective modulation, is elicited) and basal startle-blink magnitude (i.e. magnitudes of startle unaccompanied by affective modulation).

Graham (1979) has distinguished between three types of psychophysiological reflexes: (a) orienting reflexes, (b) defensive reflexes, and (c) startle reflexes. Although several studies have investigated the relationship between sensation seeking and both the orienting reflex (e.g. Neary and Zuckerman, 1976; Smith et al., 1986; Stelmack et al., 1983) and the defensive reflex (e.g. Cox, 1977; Orlebeke and Feij, 1979; Zuckerman et al., 1988), no studies to our knowledge have investigated the relationship between sensation seeking and the unmodulated startle-response (Hutchison et al., 1999, examined relations between prepulse modulation of startle and sensation-seeking but reported no unmodulated startle results).

Startle has been conceptualized as a reflex occurring when an organism experiences sudden sensory overload (e.g. Braff, 1978; Reijmers and Peeters, 1994). Because high sensation seekers are thought to have higher optimal levels of stimulation than low sensation seekers (Zuckerman, 1969), a level of stimulation considered optimal by high sensation seekers will exceed the optimal level of stimulation of low sensation seekers, thereby creating a state of sensory overload among low but not high sensation seekers. As such, less stimulation may be required by lows for a startle response to be initiated. This hypothesis was tested by examining the lowest dB level of an acoustic probe needed to elicit a startle response across groups.

In rats, the phenomenon of fear-potentiated startle has been shown to involve amygdala-based circuits, whereas the unmodulated startle blink does not (Davis et al., 1987). If sensation-seeking influences affective modulation of startle, this influence may not extend to the basic startle response. To examine this question, we investigated whether high and low sensation seekers differ in basal startle-blink magnitude in addition to measuring levels of affective startle-modulation.

In summary, the aim of the experiment was to establish high and low sensation seeking groups (with special emphasis on TAS) and to run them on three procedures: startle threshold measurement, ten trials of baseline startle, and affective modulation of startle using IAPS pictures. Directional hypotheses were made for the affective modulation of startle component with threatening compared with neutral images expected to engender more potentiation of startle in low relative to high sensation seekers. Additionally, low compared with high sensation seekers were predicted to have lower thresholds for acoustic startle. The question of group differences in basal startle was exploratory in nature and thus no predictions were made a priori.

2. Method

2.1. Participants

A total of 193 university students recruited from the departmental participant pool were screened for levels of sensation seeking. Students who scored a total of 21 or higher on the sensation seeking scale-form V (SSS-V) as well as an 8 or higher on the TAS subscale of the SSS-V were considered high sensation seekers, and students who scored a total SSS-V score of 20 or lower and a TAS subscale score of 3 or lower were classified as low sensation seekers. Of the screened students, 16 low sensation seekers (ten female and six male; mean age = 23.16 years, S.D. = 4.34) and 16 high sensation seekers (eight female and eight male; mean age = 24.94 years, S.D. = 7.63) were identified and served as study participants. The above criteria for group membership produced a high sensation seeking group with a total SSS-V score of 26 (T score = 57, percentile = 76%) and a TAS score of 9 (T score = 58, percentile = 79%), as well as a low sensation seeking group with a total SSS-V score of 11 (T score = 32, percentile = 4%) and a TAS score of 2 (T score = 29, percentile = 2%). None of the 32 participants had any hearing or visual impairments. All participants read and signed an informed consent once before screening and a second time before the start of experimental procedures and were treated in accordance with the guidelines stipulated in the "Ethical Principles of Psychologists and Code of Conduct" (American Psychological Association, 1992).

2.2. Apparatus

Two personal computers (486DX/33 and Pentium II) were used in the experiment. The first was used to initiate the trials and to store the EMG records. The second was used to present the emotion-producing stimuli in POWERPOINT. Stimulus presentation and data recording were performed automatically by an EMG data collection program. Acoustic stimuli were presented by Coulbourn Instruments equipment through Realistic binaural headphones (Nova 40). The duration and rise-fall time of the acoustic stimuli were controlled by Coulbourn equipment.

The EMGs were measured as described in previous studies (Dycus and Powers, 1997, 2000; Powers et al., 1997). The responses were amplified by a differential AC amplifier (A-M Systems Model 1700, band pass 3 dB points at 300–5K Hz) with an amplification factor of 10,000. They were collected (4000 Hz sampling with 12-bit precision: DT 2801-A, Data Translation, Inc., Marlborough, MA) and stored on the computer that initiated the trials. The time constant was 250 μs. The record length was set at 300 ms, with the stimulus being triggered 100 ms after the beginning of each record. During the data storage process, the computer rectified the record, integrated the muscle activity, and stored each trial individually.

2.3. Materials

The stimuli for the emotional modulation part of the experiment were 45 IAPS images[1] depicting 15 positive events (e.g. food, attractive infants, non-nude erotica, etc.), 15 neutral events (e.g. household appliances, furniture, silverware, etc.), and 15 threatening events (e.g. pointed weapons, hostile looking animals, ignited bombs, etc.). Threatening images rather than images of physical mutilation were used as the negative stimuli because we hypothesized that high and low sensation seekers would differ more in their reactions to such stimuli. Nude erotica were not included among positive pictures because of concerns that the institutional review board would object to having students exposed to such images. Positive images, neutral images, and images with threatening content were chosen based on previously collected ratings of valence, arousal, or both (Lang et al., 1988). Such ratings were scored on 9-point Likert scales with 1 indicating negative valence and low arousal and 9 indicating positive valence and high arousal. Images were chosen such that average ratings of valence were lowest for threatening images (3.01), second lowest for neutral images (4.96), and highest for positive images (7.67).

Although arousal levels for positive (5.38) and threatening (6.24) images were originally thought to be matched, we later found that this modest difference in arousal was significant, $t(18) = 2.88$, $P = 0.01$. Therefore, startle results are reported both for all the slides and for a subset of slides from each category with mean arousal levels that are better matched (5.88 for positive and 6.12 for threatening, $P = 0.44$). Neutral IAPS images are invariably less arousing than are either positive or negative images (Lang et al., 1988) and thus, in the current study, average arousal ratings for neutral images (2.46) were substantially lower than those ratings for positive and threatening images. Consequently, differential responses to neutral versus positive or threatening images could be a function of either valence or arousal.

[1] The IAPS image numbers were as follows: (a) pleasant, 1460, 1710, 1750, 2070, 2341, 4150, 4250, 4531,4533, 4660, 5470, 5910, 7230, 7330, 7470, 8500, 8501; (b) neutral, 7000, 7002, 7010, 7025, 7031, 7035, 7080, 7090, 7100, 7150, 7175, 7217, 7235, 7490, 7491; and (c) threatening, 1050, 1300, 2681, 2692, 3130, 3210, 3550, 6020, 6230, 6244, 6300, 6350, 6370, 9622, 9630.

2.3.1. Self-report measures

Three self-report measures were completed by participants during the course of the experiment. Two of these are published measures: Zuckerman (1994) SSS-V, made up of the TAS, experience seeking (ES), disinhibition (DIS), and boredom susceptibility subscales (BS), and Spielberger et al. (1983) state and trait anxiety inventory form Y (STAI), using both state and trait portions.

The third measure, the emotional reactions questionnaire (ERQ), was created for this study and is included in Appendix A. The ERQ is a 20-item scale designed to elicit participants' self-reported emotional reactions to the ten positive and ten negative images included in the analysis. This measure was completed after participants had already viewed these 20 images during the EMG data collection portion of the experiment. For each of the ERQ items, participants re-viewed one of the 20 images and selected the emotional state that best characterized their reaction to that image the first time they saw it. Participants had a choice of nine emotional states corresponding to those included in Izard's (1991) system of emotions: (a) scared, (b) sad, (c) angry, (d) disgusted, (e) shameful, (f) guilty, (g) interested, (h) surprised, and (i) joyful. After selecting one of the nine choices, participants indicated the intensity of the selected emotional reaction on a 3-point scale denoting a little (1), some (2), or a lot (3).

This measure was designed to elicit a report of the discrete emotion experienced during slide viewing in order to establish the emotional specificity of startle modulation to pictures of different valences. Although participants had a choice of nine emotions to choose from, we were primarily interested in the reported frequency and intensity of feeling "scared" because feelings of fear are most relevant to the research question at hand.

2.4. Physiological data collection

The electromyographic (EMG) activity of the orbicularis oculi muscles was used as the measure of the reflex blink. Three Grass gold-plated 8-mm surface electrodes were affixed around the left eye with Grass electrode cream (EC-2) and paper first aid tape, one secured to the lower lid directly under the pupil, another immediately lateral to the eye, and a third, serving as a ground, to the center of the forehead.

2.5. Procedure

Subjects were screened to determine their eligibility for the study. The screening included an informed consent, the SSS-V, and the state and trait portions of the STAI. Individuals meeting the screening criteria outlined above were asked to participate in the startle-blink portion of the experiment. Those willing to participate returned to the laboratory within 6 months (range = 1–6 months) of the screening.

Upon returning to the laboratory, participants signed an additional consent form describing the experimental procedures, including the fact that some of the images were of an unpleasant nature. Participants were also informed of the sound bursts they would occasionally hear throughout testing and were instructed to ignore them.

We then secured the electrodes and headphones and seated participants in the testing room. Participants sat in a chair placed two feet in front of a switched off, 43.18-cm computer monitor located in a quiet (50 dB background noise) 1.5- by 2.0-m testing room. Participants then completed another state portion of the STAI so that we could later assess whether or not the attachment of the disk electrodes induced differential levels of anxiety among high and low sensation seekers that might then account for differences in startle blink magnitudes. Then the experiment proper began.

Three sets of acoustic startle stimuli were presented. Affective modulation was used during the third set only. Startle stimuli in all sets consisted of a 50-ms burst of white noise with an almost instantaneous rise time. The first set consisted of 15 startle stimuli with intensities ranging from 65 to 100 dB(SPL) that were separated by intertrial intervals (ITI's) ranging from 20 to 30 s. This set of probes was designed to establish acoustic startle thresholds for participants. Thresholds were determined using Cornsweet's (1962) staircase method in which stimulus intensity is increased following a non-response to the stimulus and decreased following a response to the stimulus. According to this method, thresholds are determined by computing an average of intensities of those stimuli presented after two reversals of response. Reversals of response are those points when a response is followed by a non-response or a non-response is followed by a response. During this first set of trials (i.e. threshold), responses were differentiated from non-responses via a visual assessment of EMG activity. The computer displayed each response on the screen, and any activity greater than baseline during the 100 ms following the probe was considered a response. The 300 Hz filter used in this experiment reduces background activity to very low levels (Dycus and Powers, 1997; Powers et al., 1997) and facilitates the identification of a response against background. The investigator doing the inspecting was blind to the sensation seeking status of the participants.

The first of 15 trials was set at 85 dB(SPL). Stimulus intensity for each of the subsequent 14 trials was increased 5 dB following a non-response and decreased 5 dB following a response. The only exceptions to this rule involved one participant who responded to the lowest possible intensity (i.e. 65 dB) every time it was presented. For this subject, stimulus intensity remained at 65 dB for all remaining trials. Estimates of startle thresholds were computed by averaging the intensities of stimuli falling on and after the second reversal of response.

The second set of trials directly followed the first and consisted of ten 100 dB acoustic startle stimuli. This set was used as a basal measure of startle-blink, independent of affective modulation. All stimuli in the second set were separated by a randomly determined ITI ranging from 20 to 30 s.

Upon completion of the second set, the computer monitor was turned on and the lights in the testing room were dimmed. The third set of startle stimuli (all 100 dB) were then delivered together with positive, neutral, and threatening IAPS images, which were presented in random order. Each image was presented for 6 s, followed by a randomly determined ITI of 12–26 s. Presentation of acoustic startle stimuli occurred between 2 and 4 s after slide onset. In order to enhance unpredictability of the acoustic startle stimuli, only 30 images (ten of each type) were accompanied by an acoustic startle, leaving 15 images (five positive, five neutral, and five threatening) without ensuing startle stimuli. To further enhance unpredictability, six startle stimuli were presented during a random selection of the ITI's. Thus the total number of startle stimuli in the affective modulation part of the experiment was 36. The 45 IAPS images were divided into two sets of 21 and 24 images, termed slide shows one and two. Presentation of slide shows one and two was counterbalanced to reduce any order effects.

After the completion of the third set of trials, participants completed the ERQ and were debriefed.

2.6. Analysis of EMG records

The integrated amplitude of response was calculated for each blink from the rectified EMG record, using a fixed window (70 ms) beginning about 15 ms after the onset of the stimulus (determined by visual inspection). Baseline amplitude was calculated from a 70-ms window during the 100 ms before the stimulus was delivered. For each block of trials, the mean baseline amplitude was calculated over ten trials and subtracted from the amplitude of response on every trial. Eyeblink responses to positive and threatening pictures for each participant were standardized as z scores. This transformation produced startle magnitudes relative to the mean and standard deviation (S.D.) of startles elicited by neutral pictures for that individual.[2] As such, z-transformations both standardized data and created indices of potentiation and attenuation (i.e. neutral vs. threatening and positive, respectively).

2.7. Statistical analysis

MANOVA was used to test the main effect of group, the main effect of valence, the group by valence interaction, as well as within group simple effects. In addition, MANOVAs were computed to examine the extent to which picture valence interacted with gender and order of picture shows. A MANOVA was also computed to test the difference between state anxiety measured at screening (State 1) and state anxiety measured after electrode hook-up (State 2) across high and low sensation-seeking groups. In the present study, MANOVAs were computed using Wilk's Lambda and were followed, when necessary, by paired-samples t-tests. In addition to the above MANOVAs, one-sample t-tests (with a test value of zero) were computed to assess the significance of the average z-score for positive and negative blink magnitudes for each group (i.e. high vs. low), and t-tests for independent samples were performed to analyze group differences in startle-blink thresholds,

[2] Although some choose to standardize blink magnitudes relative to the overall mean (i.e. average of blinks to positive, neutral, and negative images), we chose not to follow this procedure because the overall mean is in part driven by the modulation effects of interest and thus important variance associated with valence may be lost.

basal EMG magnitudes, state and trait anxiety, and self-reported emotional reactions to the images. In order to reduce the possibility of Type I errors, an alpha level of 0.02 was used for all statistical tests.

3. Results

Group membership criteria produced groups with higher overall sensation seeking scores for high versus low sensation seekers ($P < 0.001$), as well as higher TAS scores for high versus low sensation seekers ($P < 0.001$). Additionally, high sensation seekers were substantially higher than were lows on the ES and DIS subscales ($P < 0.01$ for all). The two groups were not, however, markedly different on BS ($P > 0.05$), and both had fairly low mean scores for this subscale (see Table 1). The results concerning the STAI and the ERQ will be discussed below.

3.1. Startle response and sensation seeking

3.1.1. Startle without affective modulation

As can be seen in Table 2, high and low sensation seekers did not display significantly different levels of either startle-blink thresholds, $t(30) = 0.25$, $P = 0.80$,

Table 1
Means and S.D.s for SSS-V, SSS-V subscales, state-trait anxiety, and ERQ—fear scores among high and low sensation seekers

Measure	Low SS[a]		High SS[a]		*t* (30)
	M	S.D.	*M*	S.D.	
SSS-V	11.46	4.34	26.03	3.00	11.04**
TAS	2.00	1.03	9.06	0.68	22.85**
ES	4.22	1.76	6.88	1.02	5.22**
BS	2.31	1.53	3.50	2.10	1.82
DIS	2.94	2.17	6.59	2.47	4.44**
STAI					
Trait	43.60	13.32	36.31	8.33	1.84
State 1	39.47	11.79	34.94	12.44	1.04
State 2	37.50	10.51	32.56	9.77	1.37
ERQ-fear					
Frequency	0.27	0.23	0.19	0.15	1.40
Intensity	1.22	0.78	1.44	1.04	0.45

SS, sensation seekers; SSS-V, sensation seeking scale-form V; TAS, thrill and adventure seeking; ES, experience seeking; BS, boredom susceptibility; DIS, disinhibition; STAI, state and trait anxiety inventory; State 1, state anxiety during screening; State 2, state anxiety after electrode attachment; ERQ-fear, emotional reactions questionnaire-fear responses to the ten threatening images; frequency, number of ERQ-fear responses divided by 10; Intensity, average intensity of ERQ-fear responses. *$P < 0.01$; **$P < 0.001$.

[a] $n = 16$.

Table 2
Means, S.D.s (in parentheses), and between-group differences for startle-blink thresholds and basal magnitudes

	Low SS ($n = 16$)	High SS ($n = 16$)	t	P
Threshold[a]	79.11 (08.32)	77.75 (11.36)	0.25	0.80
Basal[b]	6288.92 (7279.74)	5664.73 (4871.32)	0.15	0.88

SS, sensation seekers.
[a] Lowest acoustic-probe decibel (SPL) required to elicit a startle-blink.
[b] Raw EMG amplitudes (in arbitrary units) in the absence of positive, neutral, or threatening images.

or basal startle magnitudes, $t(30) = 0.15$, $P = 0.88$. Additionally, none of the SSS subscales were found to be correlated with either startle-blink thresholds or basal EMGs (all P's > 0.25). Finally, startle thresholds and baseline startle magnitudes were not significantly moderated by gender (both P's > 0.47).

3.1.2. Startle with affective modulation

Descriptive statistics for raw and standardized blink magnitudes by group and valence are displayed in Table 3. There was a main effect of valence, with threatening pictures eliciting stronger standardized blink responses than positive pictures, $F(1, 30) = 14.76$, $P = 0.001$. Additionally, one-sample t-tests revealed an average blink magnitude to threatening images (standardized relative to neutral) that was significantly larger than zero, $t(31) = 3.04$, $P = 0.005$, indicating that blink magnitudes following threatening pictures were potentiated relative to neutral pictures. Average standardized blinks to positive pictures were not significantly different from zero, $t(31) = 0.27$, $P = 0.79$, demonstrating approximately equal startle magnitudes for positive and neutral images.

Table 3
Means and S.D.s of raw and standardized blink magnitudes (EMG) by group and valence

Group	n	Raw EMG's[a]			Standardized EMG's[b]	
		Pos	Neut	Threat	Pos	Threat
Low SS	16					
M		4865.98	5294.53	6715.15	−0.11	0.68
S.D.		(4022.33)	(4361.71)	(4909.09)	(0.37)	(0.92)
High SS	16					
M		4807.43	4715.46	5060.97	0.07	0.12
S.D.		(5205.15)	(5148.01)	(5333.19)	(0.43)	(0.40)

Pos, blink magnitudes following positive images; neut, blink magnitudes following neutral images; threat, blink magnitudes following threatening images; SS, sensation seekers.
[a] Raw EMG in arbitrary units.
[b] Average EMG amplitudes z-transfomed relative to neutral blinks. As such, mean blink amplitudes for pos and threat represent the degree to which such amplitudes deviate from EMG amplitudes elicited by neutral pictures.

MANOVA revealed a significant Sensation Seeking × Valence interaction, $F(1, 30) = 11.34$, $P = 0.002$, with significantly larger standardized blinks to threatening versus positive pictures among low sensation seekers, $t(15) = 4.72$, $P < 0.001$, but no such effect for high sensation seekers, $t(15) = 0.37$, $P = 0.72$ (see Fig. 1). One sample t-tests revealed that, among low sensation seekers, startle magnitudes were potentiated by threatening relative to neutral pictures, $t(15) = 2.99$, $P = 0.009$, and unmodulated by positive relative to neutral pictures, $t(15) = 1.18$, $P = 0.26$. Among high sensation seekers, blink magnitudes were not modulated by either threatening or positive pictures (both P's > 0.24). Between-group simple effects revealed a trend for greater potentiation to threatening images among low versus high sensation seekers, $t(30) = 2.25$, $P = 0.032$, and no group effect for attenuation to positive images ($P > 0.20$). Finally, valence did not interact with gender or the order of picture shows (both P's > 0.13).

As described in Section 2, we selected slides from the positive ($n = 8$) and threatening ($n = 7$) categories so that the mean arousal levels were not significantly different and reanalyzed the EMG data for those slides only. Results did not change. The significant group by valence interaction was still present, $F(1, 30) = 6.52$, $P = 0.016$, as were the significant effect of valence among low sensation seekers, $t(1, 15) = 4.07$, $P = 0.001$, and the lack of such an effect for high sensation seekers, $t(1, 15) = 0.26$, $P = 0.80$.

3.2. Self-report questionnaires and sensation seeking

3.2.1. Anxiety

There was no difference between the groups in trait anxiety $t(29) = 1.63$, $P = 0.11$. In addition, levels of state anxiety at screening and levels of state anxiety just after

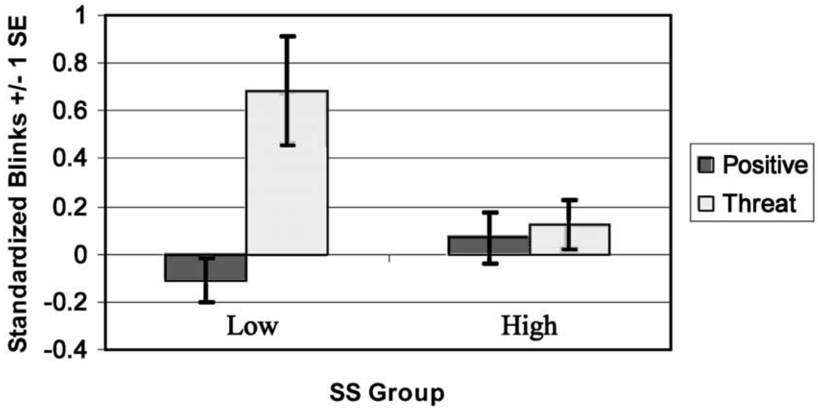

Fig. 1. Mean EMG amplitudes in standardized units (±S.E.) by group and valence. Standardization was accomplished via within-subjects, z-transformation of raw EMG data. Because such transformations were computed relative to the mean and S.D. of neutral blinks, data points reflect the extent to which positive and threatening blinks deviated from neutral blinks, with negative and positive values indicating blink magnitudes smaller and greater than neutral blinks.

electrode hook-up did not differ, $t(31) = 0.83$, $P = 0.41$, nor was there an interaction between sensation seeking status and state anxiety measured at times 1 and 2, $F(1, 30) = 0.49$, $P = 0.49$.

3.2.2. Emotional reactions questionnaire

Although fear reactions to threatening images were reported slightly more frequently by low sensation seekers than high sensation seekers, no statistical differences between the groups were found on any reported emotion or emotional intensity (all P's > 0.25).

4. Discussion

It should be reiterated that high and low sensation seekers were defined in this study as those scoring particularly high and low on the TAS subscale. As a result, findings may be said to relate to only a subset of high and low sensation seekers, namely those who are particularly high and low on the TAS subscale.

As predicted, sensation-seeking moderated levels of fear-potentiated startle such that subjects high on both the TAS subscale and the total SSS-V displayed less fear-potentiation of startle than subjects low on both these scales. Such a result may be explained by the motivational model of affect proposed by Lang and colleagues (see Bradley et al., 2001). According to this perspective, negative and positive IAPS images activate defensive and appetitive motivational systems, respectively. Specific behavioral repertoires are associated with defensive (e.g. withdrawal, escape) and appetitive motivational states (e.g. approach, procreation). Thus the lack of startle potentiation to threatening IAPS images among high sensation seekers may reflect the absence of activation in the defensive system which, in day-to-day living, may translate into the absence of "withdrawal-type" behaviors in the presence of physical threat. This idea fits well with the phenomenology of high sensation seeking, in which participation in physically risky activities is a central feature.

The present results are not likely to be due to differences in general arousal evoked by differently valenced images because, even when arousal levels were matched, the effect occurred. Furthermore, the effects of sensation seeking on fear-potentiated startle found in the current study were not influenced by differential levels of trait or state anxiety in high and low sensation seekers because the groups did not differ on either of these measures.

Although differential levels of startle modification between high and low sensation seekers were found using a psychophysiological measure (i.e. EMG), they were not seen in the data from the ERQ, a self-report measure of participants' emotional reactions to the images. There are several possible explanations for this finding. First, it may be that physiological measures of emotion are more sensitive than self-report. Second, the ERQ was completed after the participants had already seen the IAPS images once and their reactions were probably not as intense as they had been the first time. Even though participants were asked to rate the emotional reaction they had to the slides the first time they were viewed, their potentially reduced reactions during the second viewing may have influenced their self-reports.

Additionally, the design of the ERQ may have impeded the accuracy of the self-reported fear reactions measured by the scale. The ERQ instructed participants to select one of nine emotions, which best characterized their reaction to a given image. It is possible, however, that participants' reactions consisted of more than one emotion. For example, a participant may have felt both surprised and scared after viewing an image of a pointed gun but only endorsed "surprised" as their emotional reaction. In such a case, no measure of the fear component of their reaction was possible. The ERQ was designed in this way to try to establish the emotional specificity of blink modulation. In other words, we wanted to examine whether participants reported fearfulness during threatening pictures that may have accompanied the potentiation of startle. Finally, the ERQ was designed for the present study and has not been tested for reliability and validity.

4.1. Comparison to previous findings

Although the moderating effect of sensation seeking on affective modulation of startle has not been previously documented, it is consistent with the results of Corr et al. (1995) who found no fear-potentiation of startle in response to negative IAPS images among individuals low on harm avoidance (HA). HA, a subscale of Cloninger's tridimensional personality questionnaire (Cloninger, 1988), measuring the extent to which an individual reports anticipatory worry, fear of uncertainty, shyness with strangers, fatigability, and asthenia, has been found to correlate negatively with the SSS-V (McCourt et al., 1993). As such, the lack of fear-potentiated startle among high sensation seekers found by the current study is compatible with the lack of such potentiation found among individuals low on HA by Corr and colleagues. Unlike the present study, however, Corr et al. (1995) found attenuation of eyeblinks to pleasant stimuli in low HA subjects but not in high. Thus their results differ somewhat from those of the present study.

The current results are also consistent with the lack of potentiation to negative stimuli among psychopaths (Herpertz et al., 2001; Patrick et al., 1993; Patrick, 1994), a group found to be high on the sensation-seeking personality trait (Blackburn, 1987; Deforest and Johnson, 1981). Although it is unclear whether it is the sensation-seeking disposition or some other aspect of psychopathy that is responsible for this lack of potentiation, these findings provide examples of a high sensation-seeking samples demonstrating a lack of startle potentiation similar to what was found in the present study.

It is currently unclear whether the similar pattern of startle results produced by sensation seeking, HA, and psychopathy is due to correlated or overlapping components of these constructs. Studies are currently underway in our laboratory to examine the unique and combined contributions of sensation seeking, HA, and psychopathy to affective startle modulation.

4.2. Neurophysiological implications of study results

High and low sensation seekers did not have different startle-blink thresholds nor did they display different basal startle-blink amplitudes. Sensation seeking moderated the startle blink only when the reflex was affectively modulated. This dissociation between the effects of sensation seeking on the startle reflex with and without affective modulation is consistent with current understandings of the neural circuitry underlying the startle reflex (for a review, see Davis et al., 1993).

Davis and colleagues found that the fear-potentiated component of the startle reflex in rats requires circuitry related to, yet independent of, the basic circuitry required for the unmodulated startle blink (Davis et al., 1987). The obligatory circuitry in rats (and probably humans) is restricted to the brainstem (Davis and Gendelman, 1972). The fear-potentiated component of the startle-reflex in rats involves the structures in the brainstem comprising the obligatory circuitry but also requires the activation of the central nucleus of the amygdala. Here the central nucleus of the amygdala serves as a part of a secondary and independent circuit that moderates the activity of the primary reflex pathway. It, therefore, seems possible that two organisms could have similar primary startle reflexes and yet display disparate levels of fear-potentiated startle if they have similarities in the obligatory circuitry but differences in the central nuclei of the amygdala. In the current study no evidence of group differences in the primary blink-reflex was found, but groups were found to differ in levels of fear-potentiated startle. Such results may support the notion that high and low sensation seekers share similar obligatory circuitry in the brainstem but are differentiated by disparate levels of activity in the central nucleus of the amygdala. Although this claim requires the application of animal study results to a human sample and must, therefore, be phrased tentatively, it may facilitate a move toward a more specific psychobiological understanding of sensation seeking.

4.3. Implications for resilience literature

Researchers on resilience have emphasized the importance of temperament and personality in predicting resilience (Garmezy, 1985; Rutter, 1979; Rutter et al., 1979). Although studies have identified such temperamental dispositions as distractibility, stimulus–threshold sensitivity, response to novel stimuli (Wertlieb et al., 1989), neuroticism (Bolger, 1990; McCrae and Costa, 1986), and optimism (Carver et al., 1993; Scheier et al., 1994) as moderators of resilient responses to stress, sensation seeking has generally not been considered a factor affecting resilience. As a result, current theoretical models of resilience have not included sensation seeking in their respective clusters of temperamental factors (e.g. Glantz and Sloboda, 1999; Kumpfer, 1999). The results of the current study point to sensation seeking as a predictor of resilient adaptation to physically threatening visual stimuli. As such, schematic conceptualizations of resilience may account for more of the inter-individual variability in resilience by including the sensation-seeking dimension of personality in their models.

5. Conclusion

Previous studies suggest a stress buffering role for sensation seeking in the face of physical threat. Given the current results suggesting less anxious reactivity to threatening images among high versus low sensation seekers, it is plausible that reduced anxious reactivity to threat plays a central role in the stress-buffering function of sensation seeking. Of note, startle attenuation was not elicited by positive images among high or low sensation seekers suggesting that positive images selected for the current study were not arousing enough to prime the appetitive motivational system.

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Appendix A: Emotional reactions questionnaire

Directions: The slides will now be presented a second time. After each picture, please indicate the way the picture made you feel the first time you viewed it. Please circle only one choice (a, b, c, d, e, f, g, h, or i) for each of the 20 pictures. After you choose one of the nine choices indicate whether you felt that way a little, some, or a lot by circling the number 1, 2, or 3 on the right side of this form. For example, if a picture made you feel a little scared you would circle “a” (scared) on the left side of the page and “1” (a little) on the right side.

										Little	Some	a lot
1. rabbit	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
2. dog	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
3. erotica	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
4. girls	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
5. gun	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
6. baby	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
7. kissing	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
8. snake	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
9. mask	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
10. plane crash	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
11. money	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
12. electric chair	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
13. gold	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
14. fireworks	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
15. bloody man	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
16. rifle	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
17. puppies	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
18. astronaut	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
19. knife	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3
20. dead man	(a) scared	(b) sad	(c) angry	(d) disgusted	(e) shameful	(f) guilty	(g) interested	(h) surprised	(i) joyful	1	2	3

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