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Electrophysiological correlates of emotional processing in sensation seeking

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ABSTRACT

Previous studies have consistently reported a relationship between sensation seeking and emotional reactivity. However, little is known about the neural correlates and the time course of emotional processing in sensation seeking. The present study addressed these issues by recording event-related potentials (ERPs) during an emotional oddball task. Valence effect was significant at N2, P3 and LPP whereas arousal effect was significant at P3 and LPP. More importantly, low sensation seekers (LSSs) exhibited an increased emotional N2 whereas high sensation seekers (HSSs) showed an enhanced emotional P3. Furthermore, the arousal effect was similar across the two groups, but the valence effect at N2 stage was significant in LSSs instead of HSSs. These findings suggest that LSSs tend to show a more active general alerting system toward emotional stimuli, particularly for negative stimuli, whereas HSSs tend to display a stronger preference for intense stimulation irrespective of the emotional valence.

1. Introduction

Sensation seeking is a personality trait that can be characterized by "the seeking of varied, novel, complex and intense sensations and experiences, and the willingness to take physical, social, legal, and financial risks for the sake of such experience" (Zuckerman, 1994, p. 27). This trait is associated with risky driving, promiscuous sexual activity, excessive gambling and substance abuse (Bardo et al., 1996; Roberti, 2004; Zuckerman, 2007). One promising explanation for this phenomenon is the arousal theory advocated by Zuckerman. Initially, this concept was based on individual differences in optimal levels of arousal (Hebb, 1955). Relative to low sensation seekers (LSSs), high sensation seekers (HSSs) might have a basal level of under-arousal, which leads to a compensatory search for novel and exciting experiences (Zuckerman, 1969). However, this hypothesis is somewhat at odds with the evidence from studies using measures of skin conductance level, EEG and resting heart rate. Thus, the hypothesis has been replaced by the notion that HSSs and LSSs have different degrees of arousability (Zuckerman, 1997). Specifically, compared with LSSs, HSSs have the same basal level of arousal, but they habitually react less to stimulation. In this connection, HSSs need more intense stimuli to reach an optimal level of arousal.

According to Zuckerman (1990), the core basis for sensation seeking is individual differences in response to novel and intense stimuli, which are expressions of the approach and withdrawal mechanisms in humans. In comparison, HSSs have a stronger skin conductance response to novel stimulation than LSSs, especially to sensation seeking trait-related stimuli such as violent and sexual words (Smith et al., 1986, 1989, 1990). Similarly, HSSs tend to exhibit a stronger orienting response (heart rate deceleration) to novel stimuli with moderate intensity, whereas LSSs display a defensive response (heart rate acceleration) (Orlebeke and Feij, 1979). In addition, HSSs respond with an augmented cortical reaction when the intensity of a stimulus increases, while LSSs tend to display a reduced pattern (Carrillo-de-la-Peña, 1992; Zuckerman, 1990).

Given these distinct psychophysiological profiles, it is reasonable to believe that HSSs and LSSs should differ in their responses to emotional stimuli. Indeed, increasing evidence has indicated that sensation seeking, like other personality traits such as extraversion and neuroticism, has an obvious emotion component (Blaskey et al., 2008; Carton et al., 1992, 1995; Joseph et al., 2009; Lissek et al., 2005; Lissek and Powers, 2003; McCann et al., 1990; Ridgeway et al., 1984; Smith et al., 1986, 1989, 1990; Straube et al., 2010; Zaleski, 1984). For example, Zaleski (1984) found that LSSs had a clear preference for positive stimuli compared with negative and neutral ones whereas HSSs showed a stronger liking for both positive and negative stimuli compared with neutral ones. Furthermore, several previous studies reported that sensation seeking in normal individuals correlated negatively with anhedonia (McCann et al., 1990), an inability to experience or seek pleasure, as well as in patients with

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psychopathological issues (Carton et al., 1995; Watson and Jacobs, 1977).

Recently, psychophysilogical methods have been adopted to examine the relationship between sensation seeking and emotional processing. By adopting a measure of electromyography (EMG) activity, Lissek et al. found that relative to HSSs, LSSs exhibited an affective startle potentiation during exposure to threatening versus neutral images (Lissek and Powers, 2003) as well as during the anticipation of aversive stimuli (Lissek et al., 2005). However, no group differences were observed with regards to affective modulation by positive versus neutral images (Lissek and Powers, 2003). More recently, researchers using functional magnetic resonance imaging (fMRI) have begun investigating the neural correlates of emotional processing in sensation seeking. Joseph et al. (2009) found that the brain activity of emotion was modulated by sensation seeking. Regardless of emotional valence, HSSs showed early and strong activation in the insula and posterior medial orbito-frontal cortex, areas associated with arousal and reinforcement. In contrast, LSSs displayed stronger and earlier activation in the anterior cingulate (ACC) and anterior medial orbito-frontal cortex, areas involved in emotional regulation, with a greater sensitivity to the valence of emotion stimuli. The authors concluded that there was an overactive approach system in HSSs and a stronger emotional inhibitory system in LSSs. In another fMRI study, sensation seeking was correlated positively with brain responses to threat versus neutral film clips in the visual areas, thalamus and anterior insula (Straube et al., 2010). However, the relationships of sensation seeking with thalamus and insula were due to the lower activation in HSSs compared with LSSs during the neutral movie clips, which was contrary in part to Joseph et al.'s findings.

Although studies with peripheral physiological measures (e.g. EMG) and functional brain imaging methods (e.g. fMRI) have obtained some evidence for the association between emotional response and sensation seeking, event-related potentials (ERPs) provides a unique possibility to investigate in detail the time course of emotional processing in sensation seeking. Several ERP components have been shown to index different stages of emotional processing (Olofsson et al., 2008). A centro-frontally negative component labelled N2 (200–300 ms), as an index of early attentional process (Folstein and Van Petten, 2008), is modulated by emotional valence (Carretié et al., 2001, 2004; Li et al., 2008). The N2 component is followed by a parietally maximal P3 (300–500 ms) component which is elicited by task-relevant infrequent stimuli. The P3 component reflects the process of categorizing an event (Kok, 2001) or updating representations in working memory (Donchin and Coles, 1988), with its amplitude increasing as a function of attentional resources engaged (Polich and Kok, 1995). Both the P3 and the following slow sustained positivity (i.e. the late positive potential, LPP; beginning about 500 ms post-stimulus) are also influenced by emotional saliency. Despite some similarities with the P3, the LPP may involve a different neural process and reflect the sustained attentional processing of motivationally relevant stimuli (for a review, see Hajcak et al., 2010).

To the best of our knowledge, however, the corresponding ERP studies examining the relationship between emotional activity and sensation seeking are as yet lacking. Thus, the present study seeks to address this issue. To this end, we collected ERPs when high and low sensation seekers were performing an emotional oddball task, which has been extensively adopted in emotional ERP studies (Briggs and Martin, 2009; Rozenkrants and Polich, 2008; van Lankveld and Smulders, 2008).

In previous emotional ERP studies, the fact that high arousing negative or positive stimuli are used in comparison to neutral ones of low arousal might cause confusion between valence (negative–positive) and arousal (calming–arousing) dimensions in emotional processing. In recent years an increasing number of ERP studies has been published which are devoted to investigating the relationship between valence and arousal effects in emotional processing. The results show that the valence effect typically occurs at relatively early stages whereas the arousal effect is more pronounced at relatively late stages (for a review, see Olofsson et al., 2008). Therefore, the relationship between sensation seeking and emotional processing might be differentially modulated by these two emotional dimensions. Thus, the emotional stimuli employed in the current experiment consisted of different valence and arousal values which should allow for further insights into the relationship between sensation seeking and emotional processing.

Based on the previous findings, we hypothesised that: (a) valence should modulate the early ERP component whereas arousal should be more significant at the late ERP component; (b) LSSs should be more cautious about the emotional stimuli at the early attentional stage and HSSs should display a greater preference for the emotional stimuli at the late appraisal stage; (c) LSSs should exhibit stronger valence effects than HSSs, while HSSs should present greater arousal effects than LSSs.

2. Methods

2.1. Participants

Thirty-two neurologically and psychiatrically normal volunteers served as participants and received payments for their participation. All had normal or correct-to-normal visual acuity and were right-handed as determined by self-report. This research was approved by the Ethical Committee of Dalian Medical University in accordance with Declaration of Helsinki and all participants gave their written and informed consents to participate in the experiment.

All participants were selected on the basis of the scores on the Sensation Seeking Scale Form V (SSS-V; Zuckerman, 1994; Chinese version validated by Wang et al., 2000). Based on forced-choice, this scale is designed to measure four factors of sensation seeking (10 items each): thrill and adventure seeking (TAS), experience seeking (ES), disinhibition (Dis) and boredom susceptibility (BS). Summing all the 40 items derives an overall sensation seeking score. Our high sensation seeking group consisted of 16 subjects (8 female) culled from those who scored among the top 25% of 234 students, while the low sensation seeking group consisted of 16 subjects (8 female) who scored in the bottom 25%. Table 1 shows the reliabilities (Cronbach's alpha) of the SSS-V and the demographic information of the entire sample.

Because there has been some evidence to suggest that substance use influences the P3 amplitude, we solicited information regarding substance use behavior in our subjects. All participants filled out a self-report questionnaire concerning substance use with items that asked about typical frequency of cigarette, alcohol, caffeine and drugs. The data indicated that only one of the HSSs smoked cigarettes weekly. With regards to alcohol, only two LSSs drank monthly. With regards to caffeine, two HSSs consumed caffeine monthly, one consumed it daily (about one cup per day) and two LSSs consumed it daily (about 1–2 cups per day). None had any history of drug use.

2.2. Stimuli

An emotional oddball paradigm was adopted in the present study. The standard stimulus was a non-picture composed of a red/white pattern of 2 cm triangles which had been employed in previous emotional ERP studies (e.g. Delplanque et al., 2004; Olofsson and Polich, 2007). The target stimuli consisted of 80 unique pictures from the Chinese Affective Picture System (CAPS) (Bai et al., 2005), which is developed in a similar way to the International Affective Picture System (IAPS) but is used to avoid the culture bias of emotional response by the IAPS in Chinese participants. All target stimuli included 20 high arousing-positive scenes, 20 low arousing-positive scenes, 20 high arousing-negative scenes and 20 low arousing-negative scenes (see Appendix A for the CAPS number and description of each stimulus in each category). The target stimuli were selected on the basis of their normative valence and

Table 1
Reliabilities (Cronbach's alpha) of the SSS-V and demographic information ($M \pm SD$) of the entire sample.

	Alpha	Total sample ($n = 234$)
Sex (M/F)		95/139
Age (years)		22.77 ± 0.70
Thrill and adventure seeking score	0.685	6.10 ± 2.35
Experience seeking score	0.485	3.66 ± 1.94
Boredom susceptibility score	0.426	2.26 ± 1.61
Disinhibition score	0.548	3.56 ± 1.95
Sensation seeking score	0.750	15.58 ± 5.37