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The time course of novelty processing in sensation seeking: An ERP study

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ABSTRACT

Novelty processing is critical for human survival in a rapidly changing environment. However, how and when the orientation attention reflected by novelty processing is modulated by personality elements such as sensation seeking is still opened. The present study investigated the time course of novelty processing in sensation seeking by recording the event-related potentials (ERPs) in a visual novelty oddball task. High and low sensation seekers performed a visual oddball task, in which participants were instructed to detect an inverted triangle (target) and ignore both upright triangle (standard) and unrepeated line drawings of pseudo-objects deviant from participants' long-term memory (novelty). While there were no group differences in ERPs to standard and target stimuli, ERPs to novel stimuli showed a strong modulation by sensation seeking trait. The low sensation seekers, compared with the high sensation seekers, exhibited an increased N2 to novel stimuli at frontal sites. Moreover, the Pd3 component reflecting purely novelty processing was enhanced and less habituated in the high sensation seeking participants. The current findings implicated that low sensation seekers showed sensitivity to novelty detection, whereas high sensation seekers displayed stronger and more sustained novelty appraisal.

1. Introduction

As a synonymy of motivation to some extent, sensation seeking is a personality trait defined as the tendency to seek out thrilling and exciting activities and to take risks as well as to avoid boredom (e.g. Zuckerman, 1994; Zuckerman et al., 1978; Zuckerman et al., 1974). According to an influential theory (Zuckerman, 1994), sensation seeking is associated with the appetitive motivational system and high sensation seekers show more exploratory behavior in novel situation and stronger orienting response to novel stimuli than do low sensation seekers. However, recent reports established the correlation between sensation seeking and the aversive–withdrawal system, indicating that compared with high sensation seekers, low sensation seekers present higher cautiousness about and are more easily sensitive to the environmental changes (Joseph et al., 2009; Lang et al., 2005; Lissek et al., 2005; Lissek and Powers, 2003).

It is well documented that human ability to respond rapidly to novel events is fundamental to survival, which has been linked to individual differences including development (Stige et al., 2007), age (Fjell and Walhovd, 2005; Knight, 1987), gender (Matsubayashi et al., 2008) and personality (Klein et al., 1999; Matsubayashi et al., 2008). As one of the key features relevant to sensation seeking, the preference for processing novelty has been investigated using neuro-imaging methods. For example, a functional magnetic resonance imaging (fMRI) study showed enhanced activation in prefrontal, posterior temporal regions and the hippocampus in high experience seekers, suggesting a tendency to search for novel stimulation in experience seekers (Samson et al., 2009). To high arousal stimuli, interestingly, while high sensation seekers showed stronger activation in brain regions associated with arousal and reinforcement, low sensation seekers showed greater activation in regions involved in emotional regulation, with higher sensitivity to the emotional stimuli than did high sensation seekers. These data suggested distinctive neurobiological basis between two groups, i.e. an overactive approach system in higher sensation seekers and a stronger inhibitory system for low sensation seekers (Joseph et al., 2009). However, the time course of processing novelty in high and low sensation seekers has not been investigated widely. In the present study, we will assess this question by recording event-related potentials (ERPs) elicited by visual novel stimuli, which reflects real-time changes in neurophysiologic activity.

Several ERP components may index different stages in processing novel stimuli. Of particular relevance is a frontally oriented P3 component, the novelty P3 (sometimes P3a). This component is elicited by unexpected, task-irrelevant novel (infrequent) events and peaks at around 300 ms post-stimulus onset. Different from the target P3 (P3b) elicited by task-relevant oddball (infrequent) stimuli that is thought to reflect the updating of working memory related to stimulus expectancy (Donchin and Coles, 1988) and the allocation of attention resources toward the processing of target events (Polich and Kok, 1995), the

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novelty P3 component represents the automatic orienting response to new salient stimuli and marks the preferential allocation of attention resources to potentially significant events (Daffner et al., 1998).

Another ERP component related to novelty processing is the novelty N2 (N2b), a negative-going deflection between 180 and 325 ms after stimuli onset, with the scalp distribution of frontal area (for a review, see Folstein and Van Petten, 2008). Compared with the novelty P3, the novelty N2 is generally elicited automatically in auditory modality or semi-automatically in visual modality (Daffner et al., 2000a; Folstein and Van Petten, 2008; Näätänen and Picton, 1986). It has been suggested that the novelty N2 indeed reflects categorization, automatic and controlled mismatch between a stimulus and a mental template (i.e. the novelty detection) as well as affective experiences (Deldin et al., 2000; Folstein and Van Petten, 2008; Woods and Alain, 2001).

To our knowledge, only one previous ERP study investigated the novelty processing of sensation seeking with a three oddball paradigm and showed that whereas neither target P3 nor novelty P3 was modulated by sensation seeking trait, the extreme sporters exhibited higher habituation for novelty P3 than did the low sensation seekers (Fjell et al., 2007). The authors considered that the neurobiological differences between high and low sensation seekers were more related to habituation of novelty rather than to novelty detection and processing per se. Unfortunately, in Fjell et al.'s study a single repeated blue rectangle as the novel distracter was randomly inserted into the sequence of standard (i.e., a blue circle) and infrequent target (i.e., a blue circle a bit bigger than the standard) stimuli. It is possible that the habituation effect of sensation seeking for novelty P3 component could be due to the deficient novelty. To this end, the relationship between the novelty processing habituation and the sensation seeking is still unclear.

To investigate the neural mechanisms of novelty processing in sensation seeking, we recorded ERPs with a visual novel oddball task, in which, unlike Fjell et al.'s study, candidates of novel stimuli were unfamiliar and deviant from participants' long-term memory and proved to successfully dissociate the novelty N2 and the following novelty P3 components in previous studies (Chong et al., 2008; Daffner et al., 2000a; Folstein and Van Petten, 2008). Furthermore, it has been well demonstrated that novelty processing is modulated by sensation seeking trait (Samson et al., 2009; Zuckerman, 1994). In the present study, we hypothesized that sensation seeking would be relevant to different processing stages of novelty processing. If sensation seeking affects novelty detection, the novelty N2 would differ for high and low sensation seekers. If sensation seeking modulates novelty evaluation, we expected different novelty P3 between high and low sensation seekers. Moreover, it has been shown that the appetitive and aversive motivational systems are mediated by sensation seeking. Whereas low sensation seekers present high aversive motivational system, the appetitive motivational system is more dominant in high sensation seekers (Joseph et al., 2009; Lang et al., 2005; Lissek et al., 2005; Zuckerman, 1994). Thus, we speculated that the two motivational components in sensation seeking would be linked with the two different aspects of novelty processing.

2. Methods

2.1. Participants

Forty young adults (20 female, all right-handed) with normal or corrected-to-normal visual acuity served as participants and received payment for their participation. All participants reported being free from neurological or psychiatric disorders and were provided written, informed consent. This research was approved by the Ethical Committee of Dalian Medical University in accordance with Declaration of Helsinki.

All the participants, consisted of students from the Dalian Medical University, were divided into two groups (high sensation seekers and low sensation seekers) according to their sensation seeking scores. Two hundred and seventy two persons answered the Sensation Seeking Scale Form V (mean = 17.20, standard deviation = 5.22). In order to enlarge the sensation seeking trait, we selected, instead of using the popular median split method, the persons with highest and lowest scores as high or low sensation seekers respectively. Table 1 summarizes the basic characteristics of the participants selected for the present study. The two groups differed significantly only in sensation seeking score ($p<0.001$) with no difference in age, gender, and educational level.

2.2. Sensation seeking assessment

Sensation seeking was assessed using the 40 items from the Sensation Seeking Scale Form V (SSS-V, Zuckerman, 1994). Based on forced-choice, this scale is designed to measure four dimensions of sensation seeking (10 items each): thrill and adventure seeking, experience seeking, disinhibition, and boredom susceptibility. The SSS total score for all the 40 items derived an overall measure of sensation seeking. Reliability and validity of this scale have been proven to be good in Chinese culture (Wang et al., 2000).

2.3. Stimuli

A visual novel oddball paradigm was used in the present study. The standard (80%) and target (10%) stimuli were white triangle drawings presented on black background (Fig. 1). The target was an inverted standard stimulus. Novel stimuli (10%) consisted of 48 different figures, each shown only once during the experiment. All novel stimuli, which came from the collection of shapes used by Kroll and Potter (1984), were white and black line drawings of pseudo-objects that could not exist in real world. At 100-cm distance from the participants, stimuli appeared within a fixed box subtending a visual angle of approximately 7.27 × 6.06°, that remained on the screen at all times.

2.4. Procedures

Following electrode application, participants were seated in a dimly lit and sound-attenuating chamber facing a computer monitor (approximately 100 cm). They were told to fixate the center of the screen during the presentation of four consecutive blocks (with a short break between blocks) of 120 trials each. On each trial, participants were presented with a stimulus for 100 ms. The inter-stimulus interval (ISI) varied randomly from 900 to 1100 ms. Stimuli were delivered in pseudo-random order with the additional constraints that no more than two deviant stimuli were presented consecutively and that the number of standard, target, and novel stimuli were identical in each block. Participants were instructed to press a button to target stimuli with the index finger as quickly and accurately as possible, ignoring other stimuli. Buttons were reversed for half of the participants within each group. A practice block with standard and target stimuli only was provided to participants to ascertain that each participant could discriminate targets from standards.

Table 1
Characteristic and behavioral variable performance of target stimuli: means, ranges and standard deviations.

	High sensation seekers (N = 20)		Low sensation seekers (N = 20)	
	M (range)	S.D.	M (range)	S.D.
Sex (M/F)	10/10		10/10	
Age (years)	20.75 (20–21)	.44	20.9 (20–21)	.45
Sensation seeking score	26.95 (24–31)	2.09	11.2 (7–15)	2.71
RT (ms)	461.5 (358.0–665.5)	66.41	456.0 (373.2–569.4)	54.29
Accuracy (%)	99.6 (95.8–100)	1.1	99.3 (95.8–100)	1.2