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Harm avoidance in adolescents modulates late positive potentials during affective picture processing

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ABSTRACT

Research in adults has shown that individual differences in harm avoidance (HA) modulate electrophysiological responses to affective stimuli. To determine whether HA in adolescents modulates affective information processing, we collected event-related potentials from 70 adolescents while they viewed 90 pictures from the Chinese affective picture system. Multiple regressions revealed that HA negatively predicted late positive potential (LPP) for positive pictures and positively predicted for negative pictures; however, HA did not correlate with LPP for neutral pictures. The results suggest that at the late evaluative stage, high-HA adolescents display attentional bias to negative pictures while low-HA adolescents display attentional bias to negative pictures. Moreover, these dissociable attentional patterns imply that individual differences in adolescents' HA modulate the late selective attention mechanism of affective information.

1. Introduction

Processing of affective events is a crucial component for successful transition from adolescence to adulthood (Monk et al., 2003; Dahl, 2004). During the developmental period, some adolescents frequently experience negative emotional states (Somerville et al., 2010), while other peers often make risky choices, increasing the risk of traumatic brain injury (Maxwell, 2012). However, not all adolescents are actually suffering, and thus studying individual differences in selective attention of affective information is important for the understanding of affective development in adolescents. Numerous studies in adults revealed that individual differences in harm avoidance (HA) influence selective processing course of affective information (Taylor et al., 2011; Baeken et al., 2010; Cloninger et al., 1993). In line with this, whether HA in adolescents modulates selective attention during affective processing has yet to be determined.

In Cloninger's psychobiological model of personality, HA refers to the tendency to respond intensely to signals from aversive stimuli (Cloninger, 1986), and is related to the behavioral inhibition system (BIS) (Mardaga and Hansenne, 2007). Neuroimaging research in adults has demonstrated that individual differences in HA can modulate emotion-related brain activation in response to affective stimuli (Baeken et al., 2010; Paulus et al., 2003). To be noted, high-HA and low-HA adults report distinct behavioral performances. Individuals scoring high on HA describe themselves as fearful, pessimistic, shy, and fatigued, while those scoring low on HA characterize themselves as optimistic and outgoing risk-takers (Cloninger et al., 1993).

High-HA and low-HA adults also exhibit different electrophysiological patterns in response to negative and positive stimuli, respectively. Some findings stress an attentional bias of high-HA individuals toward negative stimuli (Most et al., 2005). One of the most extensively studied event-related potentials (ERPs) is mismatch negativity (MMN), which is considered a neurophysiological index of early sensory processing or automatic (or orienting) attention (Näätänen et al., 1978). MMN amplitude correlates negatively with HA (Hansenne et al., 2003) and indicates that HA modulates the influence of emotional (negative) context on auditory information processing (Mardaga and Hansenne, 2009a). Thus, High-HA individuals indeed exhibit attentional bias toward negative stimuli, which occupy processing resources, in turn reducing MMN amplitude for the auditory stimuli. Other research suggests that low-HA individuals exhibit attentional bias toward positive stimuli (Taylor et al., 2011). For example, low-HA adults elicit smaller N2 and larger P3 amplitudes after the presentation of positive pictures compared with neutral pictures (Mardaga and Hansenne, 2009b). Low-HA adults seem to have automatic attention bias in positive

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picture processing and allocate more attentional resources to positive stimuli.

Skin conductance response, which measures autonomic response, provides further evidence for HA modulation of selective attention toward affective stimuli. High-HA adults show longer half-recovery times after viewing negative pictures than neutral pictures (Mardaga et al., 2006); whereas low-HA adults show longer half-recovery time after viewing positive pictures (Mardaga and Hansenne, 2010). That is, High-HA adults sustain emotional reactivity to negative pictures for a longer period of time than to neutral pictures, while low-HA adults sustain longer emotional reactivity to positive pictures than to neutral pictures. From these results, we infer that individual differences in HA appear to modulate late selective attention during affective picture processing.

Late positive potential (LPP), a positive component with central-parietal scalp distribution, begins within a few hundred milliseconds after stimulus onset and is sustained for a period of seconds (Weinberg et al., 2012). The literature suggests that the LPP reflects a combination of processing the emotional significance of stimuli (e.g., LPP increases as picture arousal increases; Horan et al., 2012; Olofsson et al., 2008; Schupp et al., 2000; Weinberg et al., 2012) and late selective attention processing (e.g., cognitive appraisal and persisting perceptual analysis of emotional stimuli; Hajcak and Nieuwenhuis, 2006; Horan et al., 2012; Schupp et al., 2004; Weinberg et al., 2012) as well as attention to the emotional features of stimuli (Bradley et al., 2007; Horan et al., 2012; Schupp et al., 2000; Weinberg et al., 2012). In particular, LPP in adults is influenced by personality traits (Jiang et al., 2009) and task demands (Stahl et al., 2010). Patients with anxiety disorder exhibit enhanced LPP amplitude relative to control participants while viewing disorder-relevant pictures (Leutgeb et al., 2009; Michalowski et al., 2009). In children, LPP has been used for studying emotion regulation (Dennis and Hajcak, 2009), the development of emotions (Hajcak and Dennis, 2009; Zhang et al., 2012), and the disgust relevance of spider phobic girls in attention toward emotional stimuli (Leutgeb et al., 2010). Thus, the LPP indexes both late attentional processes and the intrinsic motivational significance of stimuli and all these processes might be modulated by individual differences.

During adolescence, alpha peak frequency increases with age (Gmehlin et al., 2011), the prefrontal cortex continues to prune (Cloak et al., 2010), and limbic reward systems develop earlier than prefrontal control regions (Casey et al., 2008; Ernst et al., 2006). Neuroimaging research has also shown that adolescents elicit enhanced amygdala responses to both fear and happiness compared with neutral facial expressions to a greater degree than children and adults (Monk et al., 2003; Williams et al., 2006). In line with this, adolescents behaviorally display heightened responses to both positive and negative environmental stimuli compared with children and adults (Ernst et al., 2006; Figner et al., 2009; Steinberg, 2005). Until now, there has been little research using LPP in adolescents to study the modulation of HA in affective processing.

The present study selected LPP as an indicator of late selective processing to investigate how adolescents' HA modulates late selective attention while viewing affective pictures. We collected ERPs from 70 adolescents while they viewed 90 images from the Chinese affective picture system (Bai et al., 2005). The emotional intensity of each picture was rated afterwards. To determine different patterns of relationships between LPP amplitude and the TCI dimensions, we performed multiple regressions of age and TCI-140 scores on emotional intensity and LPP amplitudes for positive, neutral, and negative pictures. Based on adult research above, we predicted that HA score would negatively predict LPP amplitude for positive pictures, and would positively predict LPP amplitude for negative pictures.

2. Methods

2.1. Participants

Seventy right-handed, healthy, adolescent students (ages 11.58–19.42 years, $M = 15.62$ years, $SD = 1.25$ years) were recruited from Shanghai Normal University in China and four nearby schools. All participants had normal or corrected-to-normal visual acuity. None reported a prior history of neurological or psychiatric disorders. Participants or their guardians (if participants were under 18 years of age) provided written informed consent and were paid ~$8 for their participation. The relevant institutional ethical committee approved this study.

2.2. Psychological assessment

The HA trait was assessed using Chinese version of the TCI (Cloninger et al., 1993; Chotai et al., 2003; Ma et al., 2010). Each adolescent completed a 140-item TCI (TCI-140) (Farmer and Goldberg, 2008; Parker et al., 2003) self-questionnaire before the experiment and participated in the experiment within a month after registration. The TCI-140 assesses four temperament dimensions (HA, novelty seeking, reward dependency, and persistence), and three character dimensions (self-directedness, cooperation, and self-transcendence). The response option format ranged from 1 = definitely false to 5 = definitely true. In this study, Cronbach α was 0.92 for HA, 0.87 for novelty seeking, 0.82 for reward dependency, 0.85 for persistence, 0.78 for self-directedness, 0.81 for cooperation, and 0.93 for self-transcendence.

2.3. Stimulus materials

Ninety images were selected from the Chinese affective picture system with 852 pictures of Chinese cultural background (Bai et al., 2005), a collection of standardized photographic materials resembling the international affective picture system (Lang et al., 1999). Of these Pictures,[1] 30 depicted positive events (attractive infants, fun scenes describing sports, hugging), 30 depicted neutral events (vegetation, household objects, buildings), and 30 depicted negative events (wreckage, a snake, garbage) (Zhang et al., 2012). They all differed significantly in the valence dimension [$F(2, 84) = 95.46$, $p < 0.001$; $M \pm SD$: Positive = 7.42 ± 0.16; Neutral = 4.87 ± 0.08; Negative = 2.23 ± 0.13]. In the arousal dimension, the positive and negative pictures both differed from the neutral ones [$F(1, 84) = 51.56$, 67.64, $p < 0.001$], but did not significantly differ between each other [$F(1, 84) = 1.06$, $p > 0.05$; $M \pm SD$: Positive = 5.78 ± 00.41; Neutral = 4.69 ± 0.43; Negative = 5.89 ± 0.35]. These pictures were displayed in color on a 17-inch computer monitor; E-prime 2.0 software (Psychology Software Tools Inc., Pittsburgh) was used to control the timing of all stimuli. Each picture was presented in the center of the screen and occupied a visual angle of 23° at a distance of 70 cm.

2.4. Procedure

At their arrival, participants first turned in the informed consent forms, which had been signed by themselves or their guardians (if they were under 18 years of age). Next, participants seated in a sound-attenuated, dimly lit room measuring approximately 12 m^2, and EEG sensors were attached. After participants were given detailed task instructions, the pictures were presented to participants while the EEG was recorded. Since continuous presenting of the same picture type, three or more times, could result in a set response, three pictures with one per picture type were randomly selected for each experimental block (30 randomized blocks total) to exclude the order effect of the pictures. After a fixation mark (+) was presented for 1000 ms, the word "View" appeared for 1500 ms, and then a picture was presented for 1500 ms. Next, the picture disappeared and the word "Assessment" appeared at the center of screen, cuing participants to rate the arousal intensity of the picture by pressing a button with a Likert scale ranging from 1 (extremely weak) to 9 (extremely strong) to ensure that adolescents fully focus on the content of emotional pictures, which is different from passively viewing in the previous studies (Hajcak and Olvet, 2008; Schupp et al., 2003, 2004). Approximately 3000 ms later, the screen went blank for a randomized period of time (between 1000 and 1500 ms) and the next trial began (Fig. 1).

2.5. Data collection and analysis

Raw EEG data was recorded using a Quick-cap with 64 Ag/AgCl electrodes (NeuroScan Inc., USA) and referenced to the left mastoid. Vertical electro-oculogram activity was monitored from electrodes located above and below the left eye and

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[1] The numbers of the Chinese affective picture system pictures used were: positive (004, 012, 014, 015, 018, 020, 022, 028, 029, 039, 040, 045, 073, 078, 088, 094, 102, 117, 118, 121, 138, 139, 430, 432, 437, 461, 478, 640, 675, 781); neutral (234, 287, 292, 301, 305, 310, 313, 315, 327, 329, 336, 352, 355, 386, 396, 406, 423, 459, 465, 514, 690, 730, 765, 767, 828, 829, 830, 839, 842, 843); negative (146, 158, 173, 178, 185, 187, 188, 191, 193, 199, 206, 210, 229, 233, 238, 243, 244, 246, 270, 273, 271, 276, 522, 539, 544, 572, 573, 611, 616, 624).