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Posterior P1 and early frontal negativity reflect developmental changes in attentional distraction during adolescence

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ABSTRACT

Previous studies in adults have revealed that attentional distraction modulates the late positive potential (LPP) during emotion regulation. To determine whether early visual components reflect developmental changes in attentional distraction during adolescence, we collected event-related potentials from 20 young adolescents, 18 older adolescents, and 18 young adults as they performed a distraction task (counting) while viewing affective images. Consistent with previous findings obtained in distraction studies, the distraction task (counting) reduced emotional modulation of the LPP. At an early stage of processing, counting reduced emotional modulation of P1 and increased the negativity bias of early frontal negativity (eFN) for negatively valenced pictures compared to simple viewing with no distraction. sLORETA analyses further revealed eFN indexing of rostral prefrontal cortical activation, a cortical area that has been shown in recent fMRI studies to be activated by distraction. Moreover, P1 amplitudes in young and older adolescents did not differ but were both larger than the P1s in young adults. In addition, eFN amplitudes significantly decreased with age. The dissociable distraction patterns between the posterior P1 and eFN provide evidence not only for the timing hypothesis of emotion regulation but also for different developmental trajectories of visual processing areas and the prefrontal cortex during affective processing in adolescence.

1. Introduction

When experiencing strong emotional responses or when viewing them in others there are a variety of strategies that one can take to reduce the unpleasantness of such responses. The timing hypothesis proposes that emotion regulation strategies can be distinguished by which stage in the emotion-generative process they have their primary impact (Sheppes & Gross, 2010). Distraction shifts attention away from the processing of a primary target stimulus toward the competing stimulus and operates at an early stage (Gross, 1998; Gross & Thompson, 2007; Thiruchselvam, Blechert, Sheppes, Rydstromb, & Gross, 2011). In contrast, reappraisal involves re-evaluating an emotional event's underlying meaning and operates at a late stage (Sheppes & Gross, 2010). A recent study using event-related potentials (ERPs) has revealed that distraction influences the elaborate meaning-evaluation of emotional stimuli earlier than reappraisal (Thiruchselvam et al., 2011). However, whether distraction modulates the early stage of affective processing is still unclear. This is the focus of the present study.

Recent fMRI studies in adults have identified that distraction reduces activation within emotional processing areas such as the amygdala (Knudsen et al., 2011). In contrast, distraction amplifies activation within attentional control areas such as the medial and dorsolateral prefrontal cortex (Kalisch, Wiech, Herrmann, & Dolan, 2006; Kanske, Heissler, Schonfelder, Bongers, & Wessa, 2010; Knudsen et al., 2011; McRae et al., 2010). However, these neuroimaging investigations did not reveal changes in the temporal processing of affective information. ERPs have high temporal resolution and are well-suited to capturing rapid neural activity related to emotion regulation. In this study we selected a few visual components to study the temporal process of attentional distraction during emotion regulation. It could determine whether distraction leads to less initial processing of stimuli versus suppressing of later processing.

The first positive event, the visual P1 component, begins at approximately 70–90 ms with a peak at approximately 80–150 ms post-stimulus, and putatively originates in the extrastriate visual cortex (Di Russo et al., 2005). The P1 amplitude indexes early sen-

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sory processing (Olofsson, Nordin, Sequeira, & Polich, 2008), is sensitive to attention allocation (Brown, Wael, & Blanchette, 2010; Luck et al., 1994; Smith, Cacioppo, Larsen, & Chartran, 2003), and is heightened for emotional stimuli compared to neutral stimuli (Holmes, Nielsen, Tipper, & Green, 2009). Separate from occipital activity (Saron, Schroeder, Foxe, & Vaughan, 2001), the early frontal negativity (eFN) is a broad negative wave over 150–300 ms (overlapping with the N1/P2/N2 complex) (Karayanidis & Michie, 1996, 1997; Kurira-Tashima, Tobimatsu, Nakayama-Hiromarsu, & Karo, 1992; Zani & Proverbio, 1995). The eFN is sensitive to attention demands (Karayanidis & Michie, 1997) and is elicited during conflict and inhibition tasks (Nieuwenhuis, Yeung, Van Den Wildenberg, & Ridderinkhof, 2003; Van Veen & Carter, 2002). In addition, the eFN might reflect an attentional mechanism of the prefrontal cortex, which generates a bias signal that either enhances or suppresses sensory representations in extrastriate visual pathways (Barceló, Suwazono, & Knight, 2000; Hillyard & Anllo-Vento, 1998; Luck, Chelazzi, Hillyard, & Desimone, 1997; Pérez-Edgar & Fox, 2003).

At the stage of elaborate meaning-evaluation of emotional stimuli, the LPP is a positive-going slow wave that is maximal at central-parietal sites, and begins approximately 300 ms after stimulus onset (Horan, Foti, Hajcak, Wynn, & Green, 2012; Schupp, Flaisch, Stockburger, & Junghofer, 2006; Weinberg, Hilgard, Bartholow, & Hajcak, 2012). The LPP is sensitive to emotion regulation strategies such as reappraisal and suppression in adults and children (Dennis & Hajcak, 2009; Foti & Hajcak, 2008; Hajcak & Nieuwenhuis, 2006) as well as affective development in adolescents (Zhang et al., 2012). To date, however, few ERP studies on emotion regulation can be found that apply these components in the study of the development of attentional distraction in adolescents.

During adolescence, the adolescent brain continues to mature; it follows a systematic trajectory of frontalization via increased synaptic pruning, continued intra-cortical myelination, and dopaminergic innervation (Rubia et al., 2000), and progressively reorganizes in a back-to-front manner (Yurgelun-Todd, 2007). With age, the prefrontal cortex progressively assumes a greater control over functions that were previously mediated by phylogenetically more primitive structures such as the visual cortices and limbic system (Casey, Getz, & Galvan, 2008). Consistent with these findings, adolescents are better able to allocate attention in accordance with task demands, to resist interference from extraneous stimulation from the environment, and to inhibit inappropriate thoughts and behavioral responses (Segalowitz, Santesso, & Jetha, 2010). However, the level of brain functioning in adolescents is still immature; for example, adolescents tend to demonstrate exaggerated responses to both positive and negative environmental cues compared to adults (Somerville, Jones, & Casey, 2010).

The present study examined whether posterior P1 and eFN reflect the developmental changes that occur within the course of attentional distraction during adolescence. We recorded ERPs from 40 adolescent students and 18 undergraduates as they performed a counting task while viewing affective pictures. The emotional intensity of each picture was subsequently rated after performance of the task. Based on the timing hypothesis of emotion regulation (Thiruchselvam et al., 2011), we predicted that the distraction (counting) task would reduce not only the LPP amplitude for positive and negative pictures but also the P1 amplitude for positive and negative pictures relative to simple viewing with no distraction. If the eFN reflects complex attention control of the prefrontal cortex (Nieuwenhuis et al., 2003; Van Veen & Carter, 2002), then we predicted that counting would enhance the eFN amplitude compared to simple viewing with no distraction. With increasing cortical efficiency less neural processing is necessary to achieve successful performance (Casey, Giedd, & Thomas, 2000; Rypma, 2007) and therefore we predicted that the P1 and eFN amplitudes would decrease with age.

2. Methods

2.1. Participants

Eighteen undergraduates and 40 adolescent students were recruited from Shanghai Normal University and four nearby schools in China. All of the participants were right-handed and had normal or corrected-to-normal visual acuity. None of the participants had a prior history of neurological or psychiatric disorders nor had they experienced anxiety or depression within the last three months. Data from two adolescents (one male and one female) were excluded due to poor-quality electroencephalogram (EEG) recordings. The final sample was classified into three age groups: young adolescents (11.78–13.62 years, 14 males and 6 females); older adolescents (15.73–16.91 years, 11 males and 7 females); and young adults (18.86–22.08 years, 10 males and 8 females). The participants or their families (if participants were under 18 years old) provided written informed consent and were compensated for their participation. This study was approved by the appropriate institutional ethical committee.

2.2. Stimuli

Visual stimuli consisted of 87 pictures from the Chinese affective picture system (Bai, Ma, Huang, & Luo, 2005), a collection of standardized photographic materials that was obtained from the International affective picture system (Lang, Bradley, & Cuthbert, 1999). Of these pictures, 29 depicted positive events (an attractive infant, a smiling face and two people hugging), 29 depicted neutral events (a scene of vegetation, a household object and a building), and 29 depicted negative events (a wreckage, a snake and a horrible face). In terms of the normalized ratings from Chinese college students (Bai et al., 2005), the three categories differed significantly in the valence dimension ($p < 0.001$; M ± SD: Positive = 7.42 ± 0.16; Neutral = 4.87 ± 0.08; Negative = 2.23 ± 0.13). The positive and negative pictures both differed from the neutral images on arousal ($p < 0.001$) but did not significantly differ between each other ($p > 0.05$; M ± SD: Positive = 5.78 ± 0.41; Neutral = 4.69 ± 0.43; Negative = 5.89 ± 0.35). Luminance (according to Photoshop™) and contrast (SD of luminance divided by M of luminance; Delplanque, N'diaye, Scherer, & Grandjean, 2007) of the images did not significantly differ between each other (all $ps > 0.05$; mean luminance and contrast: Positive = 125.3 and 0.34; Neutral = 123.5 and 0.32; Negative = 124.6 and 0.33). These pictures were presented in color on a PentiumIV computer, and E-prime 2.0 software (Psychology Software Tools Inc., Pittsburgh) was used to control the timing of all stimuli. Each picture was displayed in the center of the screen and occupied a visual angle of approximately 12° at a distance of 70 cm.

2.3. Procedure

Upon their arrival at the laboratory, the participants first turned in their informed consent forms, which had been signed by either themselves or their parents (if they were under 18 years old). The participants were then seated in a sound-attenuated, dimly lit room measuring approximately 12 m^2, and EEG sensors were attached. After the participants were given detailed task instructions, the pictures were presented to the participants while the EEG was recorded.

As illustrated in Fig. 1, a fixation mark (+) was presented for 1000 ms and a subsequent cue of "View" or "Count" appeared for 1500 ms. Next, a picture was presented for 1500 ms. Once the cue appeared, the participants were asked to perform the task (viewing or counting) until the picture disappeared. Next, the pic-