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Distraction reduces theta synchronization in emotion regulation during adolescence

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HIGHLIGHTS

- Affective pictures elicit a larger theta ERS in adolescents than neutral pictures.
- Distraction attenuates early affective modulation of theta ERS relative to simple viewing.
- Adolescents undergo age-dependent changes in oscillatory brain reorganization.

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ABSTRACT

We sought to determine if attentional distraction in adolescents can modulate event-related desynchronization or synchronization (ERD or ERS) of the theta band during emotion regulation. Event-related theta oscillations were collected from 48 adolescents and young adults as they performed a distraction (counting) task while viewing affective pictures. Consistent with data from adult participants, positive and negative pictures elicited a larger theta ERS than did neutral pictures within a 100–400 ms window, indicating that early theta ERS is indicative of motivated attention to biologically salient stimuli. Counting as a distraction strategy attenuated early affective modulation of theta ERS. Moreover, theta ERS increased with age in the anterior regions of the brain regardless of valence; however, no age differences were found in the posterior regions. These results suggest that distraction depends on a top-down attentional mechanism that disrupts theta ERS for affective pictures at an early stage. Furthermore, adolescents undergo a developmental increase in oscillatory brain reorganization.

1. Introduction

Attentional distraction is commonly used to control emotional responses and reduce stress in everyday situations and clinical settings [13], and it is important for mental health in adults and adolescents [9]. Based on the process model of emotion regulation, attentional distraction is an antecedent-focused strategy that occurs before appraisals give rise to fully developed emotional response tendencies [14,15]. Furthermore, attentional distraction shifts attention away from the emotionally salient aspects of an emotion-eliciting event to disrupt the emotion-generative process [15]. Numerous studies have determined that distraction can successfully attenuate subjective emotional experience [30,31] and pain sensations [36], downregulate amygdala and insula activity [22], and reduce the late positive potential faster than reappraisal [33]. However, these previous investigations did not access changes in event-related brain oscillations during the processing of affective information. In this study, we investigated whether distraction can modulate event-related desynchronization or synchronization (ERD or ERS) during the viewing of affective pictures.

Theta band oscillation (4–8 Hz) is one of the natural building blocks of functional signaling in the neural system, and it is related to memory, attention, and emotion [8]. The integration of the limbic system, brain stem, and cortical activity occurs based on observations that the theta band originates from multiple brain structures [17]. Motivational stimuli (e.g., erotic and threatening pictures) induced a larger theta ERS over the posterior cortical regions when compared with neutral stimuli, indicating that theta oscillation mediates motivated attention (a bottom-up process) during the early stage of an emotional response [4]. Moreover, early theta ERS was greater over the right hemisphere for negative and over the left hemisphere for positive relative to neutral stimuli [3–5,17]. A

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larger theta ERS was observed in response to positive and negative stimuli when compared with neutral images from the International affective picture system (IAPS) [19], emotional faces [6], films [12], and musical clips [26]. During emotion regulation, an attention demanding task increased theta ERS that was associated with decreased anxiety levels and other positive emotional experiences [2,18]. However, it remains unclear if distraction can modulate event-related theta oscillations during affective processing.

During adolescence, the brain has been shown to undergo structural and functional reorganization through increased synaptic pruning that begins at the caudal pole and progresses rostrally [34,36]. Moreover, the normal patterns of EEG maturation show age-related changes in the redistribution of relative EEG power [29]. In particular, a progressive developmental increase in theta synchronization is observed during adolescence [35]. All these changes in brain structure and function increase cortical efficiency later in development [10], including top-down mechanism that is involved in emotion regulation [21,38]. Thus, adolescents progressively improve their attentional allocation capacity for affective processing [29]. However, the level of brain functioning in adolescents is still immature; for example, adolescents exhibit a heightened sensitivity to environmental cues and are more vulnerable to emotional disorders (e.g., depression and anxiety) when compared with children and adults [23,32]. Therefore, understanding age differences in theta synchronization during emotion regulation is of potential interest for the clinical therapy of emotional disorders in adolescents.

The present study examined if theta ERS or ERD reflects the developmental changes in attentional distraction during adolescence. EEG data were collected from 48 adolescents and young adults as they performed a distraction task [16,27] while viewing affective pictures from the Chinese affective picture system (CAPS) [7]. Afterwards, the arousal of each picture was rated. Based on recent results in adults [3–6], we predicted that the theta ERS would increase in response to positive and negative pictures when compared with neutral pictures. Consistent with the developmental increase in theta ERS during adolescence [35], we predicted that theta ERS would increase with age. According to the process model of emotion regulation, distraction influences the emotion-generative trajectory at an early attentional deployment stage [15,33]; therefore, we predicted that a distraction (counting) task would attenuate theta ERS relative to simple viewing.

2. Methods

2.1. Participants

Forty-eight right-handed adolescent students and undergraduates were recruited from Shanghai Normal University and four nearby schools in China. All of the participants reported normal or corrected-to-normal visual acuity and had no history of unstable medical illness, head injury, or neurological illness. The subjects were classified into three age groups, including 11 male and 5 female young adolescents (11.68–13.03 years), 9 male and 6 female older adolescents (15.53–16.85 years), and 10 male and 7 female young adults (18.81–22.35 years). All of the participants, or their guardians if participants were under 18 years of age, provided written informed consent and were paid approximately $8 for their participation. This research was approved by the ethical committee of the Key laboratory of psychology at Shanghai Normal University.

2.2. Stimulus materials

Ninety images were selected from the CAPS [7]. The CAPS consists of 852 pictures with Chinese cultural background, such as Chinese cultural relics, Chinese gifts, and Chinese faces. The CAPS was chosen to avoid the cultural bias reported from use of the IAPS [19] in Chinese subjects [7,39]. Of the 90 images selected for our study, 30 depicted positive events (i.e., an attractive infant, fun scene describing sports, and hugging), 30 depicted neutral events (i.e., vegetation, household object, and buildings), and 30 depicted negative events (i.e., wreckage, snake, and horrible face) (see Supplementary material). All of the images were displayed in color on a Pentium IV computer using E-prime 2.0 (Psychology Software Tools, Inc.) to control stimuli timing. Each image was presented in the center of the monitor with a visual angle of approximately 23° and a viewing distance of approximately 70 cm.

2.3. Procedure

Upon arrival at the laboratory, all of the participants completed an informed consent form. EEG sensors were attached to participants in a sound-attenuated, dimly lit room measuring approximately 12 m^2. After participants were given detailed task instructions, pictures were presented, and the EEG was recorded. The continuous presentation of the same picture type three or more times could result in a set response; therefore, a total of three pictures from different picture types were randomly selected for each experimental block (30 randomized blocks total). After a fixation mark (+) was presented for 1000 ms, the word “View” or “Count (count backwards from 100 by three’s, i.e., 100, 97, 94, . . .)” appeared for 1500 ms, and then a picture was presented for 1500 ms. Once the cue appeared, the participants began to perform the task (viewing or counting) until the picture disappeared. During the task, the participants always viewed the picture on the screen. Next, the picture disappeared and the word “Assessment” appeared at the center of screen. This cued the participants to rate the arousal of the picture by pressing a button, using a Likert scale ranging from 1 (extremely weak) to 9 (extremely strong). After participants completed the arousal rating in approximately 3000 ms, the screen went blank for a randomized period of time (between 1000 and 1500 ms) before the next trial began. Since arousal ratings were more consistent effect than valence ratings [24] and adolescents are quite active and difficult to keep quiet for a long time, participants were instructed to only complete arousal ratings to shorten the experimental time and enhance the task involvement of the adolescent participants.

2.4. Data collection and analysis

According to the International 10–10 System, raw EEG was recorded using a Quick-cap with 64 Ag/AgCl electrodes (NeuroScan Inc., USA) referenced to the left mastoid. Vertical electrooculogram activity was monitored using electrodes located above and below the left eye, and horizontal electrooculogram activity was monitored using electrodes located at the outer canthus of each eye. Electrode gel was used to produce an impedance of less than 5 kΩ. Signals were sampled at 1000 Hz and filtered from 0.01 to 100 Hz. The continuous EEG signal was corrected for blink artifacts using an ocular artifact reduction procedure [30]. All of the data were converted offline to an average mastoid reference and low-pass filtered at 30 Hz.

According to the ERD or ERS method [25], changes in band power were defined as the percentage of decrease (ERD, positive) or increase (ERS, negative) in band power during a test interval (e.g., 1500 ms after picture onset) compared to a reference interval (e.g., −2500 ms to −1500 ms before picture onset). For each subject, the ERD or ERS was calculated within the theta (4–8 Hz) frequency band and averaged for each emotional category [3]. Overall, the head motion and muscle artifact rejections resulted in an average acceptance of 26.89 positive trials (standard deviation (SD) of 1.47),