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The development of automatic emotion regulation in an implicit emotional Go/NoGo paradigm and the association with depressive symptoms and anhedonia during adolescence

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ABSTRACT

Impaired automatic emotion regulation (AER) is closely related to major depressive disorder. Our research in adults has identified two AER-related components, Go N2 and NoGo P3, in an implicit emotional Go/NoGo paradigm. However, it is unclear whether Go N2 and NoGo P3 reflect the development of AER in adolescents and the relationship of these components with subclinical depressive symptoms and trait anhedonia. We collected EEG data from 55 adolescents while they completed the implicit emotional Go/NoGo task. After the experiment, the subjects completed the Chinese version of the Temporal Experience of Pleasure Scale and the Beck Depression Inventory. Consistent with results in adults, we determined that Go N2 represents automatic top-down attention to emotions in Go trials, whereas NoGo P3 represents automatic response inhibition in NoGo trials. These AER components exhibited age-dependent improvement during adolescence. Additionally, NoGo P3 amplitudes elicited by viewing positive faces were positively correlated with trait anhedonia, whereas NoGo P3 amplitudes elicited by viewing negative faces were negatively correlated with depressive symptoms. Our observations provide further understanding of the neurodevelopmental mechanism of AER and yield new insight into dissociable impairments in AER in adolescents with major depressive disorder during positive and negative implicit processing.

1. Introduction

Automatic emotion regulation (AER; Jackson et al., 2003), also called implicit (Koole and Rothermund, 2011) or unconscious (Williams et al., 2009) emotion regulation is pervasively used to control emotional responses in daily life, and its dysfunction has been implicated in the development of psychopathologies such as mood disorders or depression in adolescents (Rive et al., 2013). In the process model of emotion regulation (Gross and Thompson, 2007), AER can be conceptualized as the modification of any aspect of one's emotional response without conscious intent, without being aware of the emotion regulatory process and without attempting to deliberately control emotions (Mauss et al., 2007). However, measuring AER in experiments is very challenging for researchers. Fortunately, there have been several experimental strategies to garner evidence for AER. Specifically, the implicit paradigm presents emotional stimuli but requires subjects to execute a cognitive task that is not related to emotions. Thus, the experiment allows for inferences about AER-related processes by comparing emotional conditions with a non-emotional (neutral) condition (Koole and Rothermund, 2011).

Based on neuroimaging studies, Phillips et al. (2008) described a neural model of voluntary and automatic emotion regulation, which determined that AER mainly depends on the function of the ventromedial network, including the anterior cingulate cortex (ACC) (Phillips et al., 2008). However, neuroimaging studies did not reveal the accurate temporal course of AER. In contrast, event-related potential (ERP) studies with good temporal resolution can capture all levels of emotion-generation processes. By comparing the time course of different emotional stimuli, the researchers can isolate the AER-related components (Koole and Rothermund, 2011). For example, AER modulates the late positive potentials (Mocaiber et al., 2010; Zhang and Zhou, 2014) and alters two earlier ERP components, Go N2 and NoGo P3, during an implicit emotional facial Go/NoGo task (Zhang and Lu, 2012). However, these studies in adults did not reveal the developmental mechanism

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of AER in adolescents. In this study, we employed Go N2 and NoGo P3 as electrophysiological indicators to investigate the development of AER during adolescence and their links with depressive symptoms and anhedonia (Downar et al., 2014).

The Go/NoGo paradigm has been traditionally used to evaluate response inhibition related to the ACC function. However, in the experiment with an event-related design, participants need to switch between Go trials and NoGo trials. Therefore, the Go/NoGo task has possible response-switching components corresponding to different stages of information processing. In NoGo trials, frontal NoGo N2 and NoGo P3 amplitudes are greater than Go N2 and Go P3, respectively (Albert et al., 2010; Lamm et al., 2006). NoGo N2 is a negative shift with a peak between 200 and 400 ms following NoGo stimuli. NoGo P3 is a positive-going component that was evaluated in a time frame from 300 to 700 ms. Moreover, NoGo P3 is thought to directly reflect the inhibitory process itself (Albert et al., 2010; Spronk et al., 2008).

Particularly during the implicit emotional Go/NoGo task, NoGo P3 was modulated by affective facial valence in our adult study (Zhang and Lu, 2012), and the emotional valence was sufficient to evoke response tendencies (Chiu et al., 2008). In the NoGo task, emotional- and motor-response inhibition have been shown to coexist and coactivate some brain areas, including the ACC, that are associated with the interaction between emotional processing and motor inhibition (Goldstein et al., 2007; Berkman et al., 2009; Albert et al., 2011), which is observed in the P3 (but not in the N2) time range (Albert et al., 2011). Both voluntary inhibition of the motor response (button press) and implicit emotion regulation are additive and simultaneously reflected in the NoGo P3 waveform. Thus, NoGo P3 superimposes with automatic response inhibition of emotions (Zhang and Lu, 2012). In contrast, NoGo N2 amplitudes do not vary with emotional valence and represent only cognitive conflict monitoring (Albert et al., 2011). Therefore, NoGo N2 might not be linked to AER (Zhang and Lu, 2012).

The Go/NoGo paradigms with affect-loaded stimuli involve the interaction of emotion and attention (Blair et al., 2007) and provide new insight into the emotion-modulated executive attentional process (Albert et al., 2010, 2011; Hum et al., 2013). The motivated attention model proposes that affectively salient stimuli attract more attention resources than neutral stimuli (Lang et al., 1997). However, the resource theory assumes that the attention capacity is limited (Kahneman, 1973). With limited attention resources, participants have to intentionally or unintentionally exert attentional control over affective stimuli so that they can perform goal-directed behaviors (Blair et al., 2007). Thus, in the Go trials, there exists a process that is linked to the attentional control of emotions, which depends on the level of cognitive load (Pessoa et al., 2002). For instance, Go N2 is suggested to index the degree to which attentional control is demanded (Dennis and Chen, 2007). Specifically, during the implicit emotional Go/NoGo task, Go N2 amplitudes evoked by viewing emotional faces were significantly lower than those evoked by viewing neutral faces (Zhang and Lu, 2012). Generally, a stimulus-driven bottom-up process occurs within 200 ms. However, in the present study, Go N2 occurs after 200 ms. In addition, stimulus-driven attention cannot explain why Go N2 amplitudes for positive and negative faces are less negative than those for neutral faces. If Go N2 is driven by stimulus-driven attention, Go N2 amplitudes evoked by positive and negative faces should be more negative than those evoked by neutral faces. Therefore, we propose that Go N2 is altered by emotions and represents automatic top-down attention toward emotions (Zhang and Lu, 2012). In contrast, increased Go P3 amplitudes in response to positive and negative faces are in line with the viewpoint that Go P3 mirrors motivated attention (Knyazev et al., 2009; Schupp et al., 2004).

The affective Go/NoGo task can evaluate emotional response inhibition and may be useful for assessing major depressive disorder (MDD), characterized by abnormalities in deliberate or automatic emotion regulation (Chiu et al., 2008). Some findings stress the hyperactive negativity in MDD during negative affect processing (Joormann, 2010). For instance, previous studies employed explicit emotional Go/NoGo tasks where facial expressions of emotion had to be actively identified for successful performance (Han et al., 2012; Ladouceur et al., 2006). These studies found that adolescents with MDD exhibited faster reaction times to sad face Go trials embedded in neutral face NoGo trials in the moderate probability condition (Ladouceur et al., 2006). There is also an inverse correlation between depressive symptoms and reaction time to negative (angry) faces in the NoGo trials (Han et al., 2012). Undergraduates displaying a high degree of depressive symptoms exhibit larger NoGo P3 responses to negative than to positive stimuli (Krompinger and Simons, 2009). Although these results from the explicit emotional tasks disclosed negativity bias in volitional emotion regulation in depressed individuals, they did not unveil AER-related deficits in depression during implicit emotional processing.

Other studies propose that depression might originate from a reduction in positive affectivity (Davey et al., 2008; Treadway and Zald, 2011). Specifically, anhedonia is associated with a deficit in the reward-processing dopamine system, which increases the risk for depression (Liu et al., 2014). For example, using an oddball task with standard stimuli (O′s) and a deviant stimulus (X) at random times, Franken et al. (2006) found that early (70–125 ms), middle (125–175 ms) and late (300–500 ms) ERP components of subjects with a low hedonic tone were attenuated relative to subjects with a high hedonic tone. Particularly, depressed individuals exhibit reduced activation in the right ACC and caudate during reward anticipation compared to controls (Smoski et al., 2009). The positive bias in depressed individuals reduces as severity of anhedonia increases (Dunn et al., 2009). To our knowledge, however, only one ERP study has indicated that the amplitude of feedback negativity to gain feedback is related to the severity of anhedonia in depressed participants (Liu et al., 2014). Therefore, it remains unclear whether anhedonia is associated with AER in the implicit emotional Go/NoGo task.

During adolescence, continual pruning and myelination of the prefrontal cortex (Cloak et al., 2010) contribute to an increase in cortical efficiency later in the developmental process (Casey et al., 2000), including top-down mechanisms that are involved in AER, such as response inhibition (Rive et al., 2013). Thus, adolescents progressively improve their automatic inhibitory capacity for emotional processing (Wiers et al., 2007). However, the cortical function in adolescents is not fully mature because the limbic reward systems develop earlier than the prefrontal control regions (Casey et al., 2008). For example, adolescents exhibited exaggerated amygdala response to emotional expressions relative to children and adults during an emotional Go/NoGo task (Hare et al., 2008). Teenagers also had greater between-subjects ventral-dorsal striatal coactivation than children and adults for happy NoGo versus Go trials (Somerville et al., 2011), which implicates exaggerated ventral striatal representation of appetitive cues in adolescents relative to an intermediary cognitive control response (Casey et al., 2008).

The triadic model of motivated behaviors in adolescence assumes an immature supervisory role of the medial/ventral prefrontal cortex (implicated in AER) in orchestrating the contributions of the amygdala (the avoidant system) and ventral striatum (the approach system) in response to affective stimuli (Ernst et al., 2006). Thus, the development of the regulatory mechanisms lags behind the development of affective brain systems so that adolescents are more sensitive to affective stimuli and are more vulnerable to clinical depression than children and adults (Davey et al., 2008). For example, in an emotional Go/NoGo task, response inhibition is more readily disrupted by negative emotional distraction in early adolescence than at other ages (Cohen-Gilbert & Thomas, 2013). These results support the delayed development of inhibitory control. Moreover, adolescents with MDD exhibit enhanced subgenual ACC activation to fearful faces (versus neutral faces) during an implicit emotional face task (Tao et al., 2012). Therefore, clarifying developmental mechanisms in AER is of potential value for the clinical treatment of adolescent depression.