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Time course of automatic emotion regulation during a facial Go/Nogo task

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ABSTRACT

Neuroimaging research has determined that the neural correlates of automatic emotion regulation (AER) include the anterior cingulate cortex. However, the corresponding time course remains unknown. In the current study, we collected event-related potentials (ERPs) from 20 healthy volunteers during a judgment of the gender of emotional faces in a cued Go/Nogo task. The results indicate that Go-N2 amplitudes and latencies following positive and negative faces decreased more than those following neutral faces; Nogo-N2 amplitudes and latencies did not vary with valence. Moreover, positive and negative faces prompted higher P3 amplitudes and shorter P3 latencies than neutral faces in both Go and Nogo trials. These observations suggest that in the executive processes, Go-N2 reflects top-down attention toward emotions, while Go-P3 reflects only motivated attention; in the inhibitory processes, Nogo-N2 reflects cognitive conflict monitoring, while Nogo-P3 overlaps with the automatic response inhibition of emotions. These observations imply that AER can modulate early ERP components, and both Go-N2 and Nogo-P3 can be used as electrophysiological indices of AER.

1. Introduction

Automatic emotion regulation (AER), which is pervasive in daily life and important for mental health (Bargh and Williams, 2006; Mauss et al., 2007a), is attracting considerable attention from many researchers (Koole and Rothermund, 2011). As an unconscious, implicit, or impulsive process (Williams et al., 2009), AER can be defined as the changes in any aspect of an individual's emotional responses without conscious intent, without engaging in any form of deliberate emotion regulation, and without paying attention to the process of emotional regulation (Mauss et al., 2007a,b). In fact, AER can be achieved through a number of processes and can modify the subjective experience, peripheral physiology (e.g., cardiac reactivity), or expressive behavior of an emotional response (Mauss et al., 2006, 2007b; Mocaiber et al., 2011; Williams et al., 2009). Recent neuroimaging studies using the dot probe, emotional Stroop, and emotional Go/Nogo tasks have determined that the anterior cingulate cortex (ACC) is one of the neural correlates of AER (see Phillips et al., 2008a,b for a review). However, these investigations cannot reveal the time course of AER due to poor temporal resolution. In contrast, event-related potentials (ERPs) can capture rapid neural responses related to emotions. In the current study, we employed ERP to explore the time course of AER.

Emotion regulation, whether deliberate or automatic, involves changes at all levels of the emotion-generation process, including attention deployment, appraisal, and regulation of emotional behaviors (Gross and Thompson, 2007). The late positive potential (LPP), one of the most extensively studied ERP components, is sensitive to deliberate emotional regulation strategies such as reappraisal (DeCiccoa et al., 2011; Foti and Hajcak, 2008; Hajcak and Nieuwenhuis, 2006; MacNamara et al., 2011), directed attention (Ferrari et al., 2008; Hajcak et al., 2009), distraction (Thiruchselvam et al., 2011), and directions to increase and decrease subjective emotional responses (Moser et al., 2006, 2009; Krompinger et al., 2008). Several studies in children and adolescents have determined that the frontal N2 (often dubbed the "inhibitory N2") is a neurophysiological marker of inhibitory control in Go/Nogo tasks (Lewis et al., 2006a,b, 2007, 2008; Lamm et al., 2011). To our knowledge, however, only one ERP study has explored the time course of AER, indicating that the implicit reappraisal strategy modulates the LPP associated with affective picture viewing (Mocaiber et al., 2010). Therefore, it remains unclear whether AER modulates early ERP components.

As one of the classical approaches to assess ACC function, the Go/Nogo paradigm with non-emotional stimuli has reliably identified two ERP components related to response inhibition, the frontal Nogo-N2 and Nogo-P3, whose amplitudes are larger than Go-N2 and Go-P3, respectively (Albert et al., 2010; Kiefer et al., 1998). Nogo-N2 is a negative-going component that peaks around

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200–400 ms following Nogo stimuli. Subsequent to N2 in Nogo trials, Nogo-P3 is a positive-going component that peaks around 300–700 ms. The Nogo-N2 and Nogo-P3 components reflect different sub-processes of response inhibition. Many researchers suggest that the Nogo-P3 directly reflects the inhibitory process itself (Albert et al., 2010; Bruin and Wijers, 2002; Smith et al., 2008; Spronk et al., 2008). However, there is still some debate on whether Nogo-N2 reflects conflict monitoring (Donkers and Van Boxtel, 2004; Kenemans et al., 2005; Nieuwenhuis et al., 2003) or response inhibition (Bartholow et al., 2005; van Veen and Carter, 2002). Thus, Nogo-N2 may mirror a wide range of cognitive control processes, including attention control, conflict monitoring, inhibition itself, and/or error evaluation (Weissman et al., 2004; Spronk et al., 2008; Groen et al., 2007).

Incorporating affectively salient stimuli into Go/Nogo paradigms provides new insights into the processes related to emotion-modulated execution and inhibition of motor responses (Albert et al., 2010, 2011; Schulz et al., 2007; Wang et al., 2011). First, affective stimuli draw more attentional resources than neutral stimuli (Lang et al., 1997), and the emotional valence biases behavioral responses when approaching or avoiding stimuli (Hare et al., 2005). Due to limited attentional resources, participants must consciously or unconsciously exert attentional control over emotional stimuli to ensure that they execute goal-related behaviors (Blair et al., 2007; Taylor and Fragopanagos, 2005). Thus, in the executive process (Go task), a process exists that relates to the attentional control of emotions. For example, there is evidence indicating that Go-N2 signals the extent to which attentional control is required (Nieuwenhuis et al., 2003; Dennis and Chen, 2007). Second, the emotional valence is sufficient to evoke prepotent response tendencies (Chiu et al., 2008; Hare et al., 2005). Thus, in the inhibitory process (Nogo task), emotional- and motor-response inhibition 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); this interaction is observed in the P3 (but not in the N2) time range (Albert et al., 2011).

Moreover, participants use brain responses elicited by emotional stimuli during explicit or implicit tasks in different ways because emotional context can alter behavioral and biological responses (Albert et al., 2010; Carretié et al., 2006; Hare et al., 2005). In explicit tasks, participants actively use emotional stimuli as perceptual cues to guide them in accomplishing tasks (Dolan, 2002). In implicit tasks, however, participants unconsciously engage in top-down control of the ACC (or the right inferior frontal cortex) over limbic responses elicited by emotional stimuli (Albert et al., 2011; Etkin et al., 2011; Berkman et al., 2009; Goldstein et al., 2007). Therefore, there may be automatically regulated emotional processes in early conflict monitoring or in the late stages of response inhibition (Wang et al., 2011). Thus, by selecting an implicit emotional task (a cognitive task), tracing the rapid unfolding of emotional responses over time and comparing waveforms between emotional and neutral stimuli, researchers can extract the ERP components that reflect the AER from the executive or inhibitive processes. However, few investigations to date have used the Go/Nogo paradigm with affective stimuli.

The present study aimed to analyze the AER-related processes in a cued Go/Nogo paradigm. To this end, we recorded the ERPs of 20 undergraduate volunteers while they performed implicit emotional tasks in which they made only a gender judgment of emotional faces from the Chinese Face Affective Picture System (CFAPS; Wang and Luo, 2005). As noted earlier, if, in the executive process, Go-N2 reflects top-down attention of the ACC toward emotions (Nieuwenhuis et al., 2003; Dennis and Chen, 2007), then the emotional faces in the Go trials should elicit smaller N2 amplitudes and shorter latencies than neutral faces because emotionally salient faces should automatically activate the neural network for the unconscious focusing of attention to facilitate task completion (Bayle and Taylor, 2010; Eimer and Holmes, 2007). If in the inhibitory process Nogo-P3 overlaps with automatic response inhibition, then emotional faces in the Nogo trials should elicit larger P3 amplitudes and shorter latencies than neutral faces because emotional- and motor-response inhibitions interact with and activate common brain areas to cause stronger response inhibition (Goldstein et al., 2007; Berkman et al., 2009; Albert et al., 2011).

2. Methods

2.1. Participants

Twenty right-handed undergraduate volunteers (11 males and 9 females; age range from 18 to 20 years) from Shanghai Normal University participated. All participants declared normal or corrected-to-normal visual acuity and had no history of neurological illness or brain surgery. Participants provided written informed consent prior to the experiment and were paid approximately $8 for their participation. The relevant institutional ethical committee approved the study protocol.

2.2. Stimulus materials

The stimuli consisted of 162 pictures from the CFAPS using a 9-point Likert scale to assess valence and arousal (Wang and Luo, 2005). The CFAPS was chosen to avoid the cultural bias seen when the International Affective Picture System was used with Chinese subjects (Huang and Luo, 2004). With an equal number of male and female faces, these visual pictures included 54 positive (happy faces), 54 neutral (calm faces), and 54 negative (angry and fearful) faces. Positive and negative stimuli were matched according to their arousal levels, and there were no significant differences between the three picture types [$M \pm SD$: Positive = 5.62 ± 0.74; Neutral = 5.26 ± 0.59; Negative = 5.60 ± 0.71; F (2,159) = 1.86, $p > 0.05$]. In terms of the normative valence rating given by the participants, the three categories differed significantly from each other [$M \pm SD$: Positive = 6.45 ± 0.28; Neutral = 4.57 ± 0.21; Negative = 2.91 ± 0.27; F(2,159) = 84.31, $p < 0.001$]. There were no significant gender differences in valence or arousal [F(1,159) = 1.52 and 1.92, respectively, $p > 0.05$]. All pictures were presented in the center of a Pentium IV computer screen using E-prime 2.0 (Psychology Software Tools Inc., Pittsburgh) to control the timing of the stimuli and to record the response time. Each picture occupied approximately 23° of the visual angle at a viewing distance of approximately 70 cm.

2.3. Task and procedure

Upon arrival at the laboratory, the participants were first familiarized with the procedure. The participants then sat in a sound-attenuated, dimly lit room approximately 12 m^2 in size. After the sensors were attached, the participants performed a cued Go/Nogo task with an equal proportion of Go and Nogo trials to control for the novelty of the Nogo cues. Following a fixation mark (+), which was visible for 500 ms, the cue "Male" or "Female" appeared for 1000 ms, and then a picture of a face was randomly presented for 100–250 ms. The participants judged the face gender according to the preceding cue. If the cue was consistent with the face gender (Go task), the participants pushed the SPACE key with the index fingers of both hands simultaneously as soon as possible but not sacrificed accuracy. If the picture and the word cue did not match (Nogo task), the participants only viewed the image and did not press any buttons. After the judgment, a blank screen appeared for 800–1200 ms (random duration) before the next trial started. The formal experiment included 27 randomized blocks, each of which had 12 randomized trials [3 (emotional valences) × 2 (facial gender) × 2 (trial type)]. A 20-s resting baseline was inserted every 9 blocks. The entire experiment lasted approximately 28 min.

2.4. Data collection and analysis

Electroencephalographic (EEG) data was recorded using a Quick-cap with 64 Ag/AgCl electrodes (NeuroScan Inc., USA), arranged according to the International 10-10 System, and referenced to the left mastoid. Four additional electrodes were attached for a bipolar recording of the vertical electrooculogram (VEOG), located above and below the left eye, and the horizontal electrooculogram (HEOG), located at the outer canthi of each eye. Electrode gel was used to produce impedances lower than 5 kΩ. All EEG signals were digitized with a sample frequency of 1000 Hz and were online filtered from 0.01 to 100 Hz. The continuous EEG signals were offline converted into an average mastoid reference and corrected for blink artifact using an ocular artifact reduction procedure (Semlitsch et al., 1986) with a low-pass filter at 30 Hz (24 dB/octave). Epochs were generated from −200 to 1000 ms relative to the stimulus onset, with a 200 ms pre-stimulus baseline correction, and then excluded from averaging if they contained activity exceeding ±100 μV at any site.

Individual ERP averages were derived for correct trials of trial type (Go, Nogo), emotional valence (positive, neutral, negative), and facial gender (male, female). Nine sites where the N2 and P3 were most prominent (Zhang et al., 2006) [F3, Fz, F4