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Research article

Neural mechanism of facial expression perception in intellectually gifted adolescents

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HIGHLIGHTS

- High IQ group had faster response speed than average IQ group in the facial expression classification task.
- High IQ adolescents elicited faster N170 responses than average adolescents when they classified the inverted faces.
- High IQ group induced larger VPP amplitudes to the sad faces than to the neutral faces.
- High IQ adolescents evoked larger LPP amplitudes than the average IQ group for better attentional control on expressions.

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ABSTRACT

The current study investigated the relationship between general intelligence and the three stages of facial expression processing. Two groups of adolescents with different levels of general intelligence were required to identify three types of facial expressions (happy, sad, and neutral faces), which were presented with either inverted or upright orientation. Participants' response times and accuracy were measured and event-related potentials (ERPs) were recorded to evaluate neural dynamic processes. The behavioral results showed that high IQ adolescents exhibited shorter response times than average IQ adolescents during the facial expression identification task. The electrophysiological responses showed that no significant IQ-related differences were found for P1 responses during the early visual processing stage. During the middle processing stage, high IQ adolescents had faster structural encoding of inverted faces (shorter N170 latencies) compared to their average IQ peers, and they also showed better structural encoding of sad faces, with larger vertex positive potential (VPP) amplitudes than for neutral faces. During the late processing stage, adolescents with high IQ showed better attentional modulation, with larger late positive potential (LPP) amplitudes compared to adolescents with average IQ. The current study revealed that adolescents with different intellectual levels used different neural dynamic processes during these three stages in the processing of facial expressions.

1. Introduction

Human general intelligence is thought to indicate how well individuals can adapt themselves to the surrounding emotional and non-emotional environment [1]. The scientific investigation of the relationship between general intelligence and social-emotional abilities can be dated back to Terman [2], and Spearman's psychometric theory of intelligence believes that there are at least modest correlations between general intelligence and an individual's social-emotional abilities [3]. Many empirical studies also indicate that general intelligence quotient (IQ) is associated with social-emotional abilities [4–8]. Fiori and Antonakis [4] found that general intelligence could predict participant's faster responses during selective attention on emotional stimuli, which suggests that general intelligence is essential for performance involving emotional activation. Zeidner et al. [8] observed that academically gifted adolescents had better emotional abilities relative to non-gifted adolescents. However, the neural dynamic responses

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underlying the superior processing of social-emotional information by high IQ individuals have remained relatively unknown until now.

Facial expressions convey essential social-emotional information, and the accurate and rapid identification of facial expression is vital for efficient social and interpersonal communication [9]. Longer response times and less accurate performances have been reported when individuals identify faces presented inversely compared with upright faces [10], and this face inversion effect has been attributed to an individual's "visual expertise" in processing highly homogeneous information commonly presented in one orientation [11]. In addition, four event-related potential (ERP) components are thought to correlate with three different stages in the perception of facial expressions [12]. The P1 component, peaking at about 100–130 ms post-stimulus, reflects the stage of early visual processing of face categorization [13], and children with attention deficit hyperactivity disorder (ADHD) have shown a reduced inversion effect on P1 latency compared with typically developed children, which illustrates that early visual attention processing of faces is related to different cognitive states [14]. The N170 and vertex positive potential (VPP) components, with similar peak latencies (170–200 ms) but different neural generators (N170: occipito-temporal areas; VPP: fronto-central areas), correlate with the stage of structural encoding of faces/facial expressions [13,15,16]. Meanwhile, individual's emotional abilities and skills correlated with the N170 and VPP responses to facial expressions [17,18]. Finally, the late positive potential (LPP) component, peaking at approximately 300 ms post-presentation with central and parietal distributions, relates to the stage of high-level attentional modulation of affective information [19,20]. Nonetheless, the associations between general intelligence and neural activities during these three stages in the processing of facial expressions are not well known.

The main aim of the current study was to explore whether individuals with different IQ levels have different neural activity during the three stages of facial expression processing. Adolescents were selected as participants, because adolescence is a pivotal period for the development of social abilities [21], and this period has been shown to associate with facial recognition abilities [22]. In addition, schematic faces were adopted as experimental stimuli, because they are very similar to real human faces and can induce expression perception effects comparable to photographic facial expressions [23]. More importantly, by using the schematic faces, low-level physical features of faces can easily be controlled and irrelevant features relating to facial identity can be excluded. Based on Spearman's psychometric theory of intelligence and previous studies [3,4,8], it was hypothesized that high IQ adolescents would have shorter ERP latencies and greater ERP amplitudes, resulting in faster and better neural processing of facial expressions.

2. Materials and methods

2.1. Participants

Two groups of male adolescents were enrolled in the current ERP study. The high IQ group [$n = 15$; aged 13.3–14.1 years old (13.6 ± 0.3 years old)] was recruited from a special education system for intellectually gifted children. The average IQ group was selected from a normal middle school [$n = 14$, age 13–14.6 years old (13.7 ± 0.4 years old)]. The general intelligence of participants was tested using the non-verbal pencil–paper Cattell's culture fair test (55 items, 1 point/item, scale range 0–55) with four subtests involving different aspects of intelligence: classifying, completing series, solving matrices, and evaluating conditions [24]. Cattell's culture fair test has high reliability of 0.85 [4], and it has been shown to load highly on the g factor of intelligence [4,25,26]. For the IQ scores of the high IQ group, the mean with 95% confidence interval was 51.20 ± 1.06. For the IQ scores of the high IQ group, the mean with 95% confidence interval was 39.20 ± 1.94. A *t*-test showed that high IQ adolescents achieved significantly higher scores than average IQ adolescents ($t = 10.8$, $p < 0.001$). Participants' emotional intelligence abilities were measured by the Chinese version of the Emotional Intelligence Scale (EIS, a self-report test with high reliability and validity) containing 33 items with four subscales: emotion perception (EP), Managing Self Emotions (MSE), Managing Others' Emotions (MOS), and Emotional Utilization (EU) [27–29]. The results of *t*-tests showed that no significant differences were found between the two groups in their emotional intelligence abilities ($p > 0.05$). All the participants were right handed with normal or corrected-to-normal visual acuity, and none of them had a history of neurological or psychiatric illness. Written informed consent was obtained from the adolescents and their parents.

2.2. Stimuli and procedure

The stimuli were cartoon faces drawn in black and displayed on a monitor with a light-grey background, and showing either a happy, neutral, or sad expression, with its either upright or inverted orientation. There were six types of stimulus presentation: the upright happy face [up_hap], the upright neutral face [up_neu], the upright sad face [up_sad], the inverted happy face [inv_hap], the inverted neutral face [inv_neu], and the inverted sad face [inv_sad] (Fig. 1). The visual angles for each stimulus presentation were 6° vertically and 5.5° horizontally, and the viewing distance was 65 cm.

Each trial began with a central fixation "+" (lasting for 400 ms), and then the stimulus was presented for 300 ms. The inter-trial interval [ITI] varied randomly between 400 and 800 ms, and started after the participant's responses. The participant's right index finger, right middle finger, and right ring finger were required to press the appropriate response buttons, and the labels on the response buttons were counterbalanced across the participants (from left to right: happy–neutral–sad/sad–happy–neutral/neutral–sad–happy). Sessions included one block for practice and four blocks for the formal experiment. In the practice block, each participant was given 24 trials to become familiar with the experimental procedure and the response rules (four times for each type of stimulus). For each formal block, there were 25 trials for each type of stimulus, and stimuli were presented randomly. Between blocks, participants were encouraged to take a break for about 3 min, and the whole experiment lasted about 30 min.

2.3. EEG recording and data-analysis

The electroencephalograms (EEG) were recorded from 64 scalp electrodes embedded in a NeuroScan Quik-Cap, and the electrode positions were placed according to the 10–20 system.

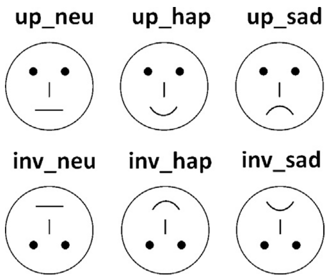

Fig. 1. Examples of happy, sad and neutral stimuli.