Brain responses to facial expressions by adults with different attachment–orientations

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Behavior studies demonstrate that the attachment–orientation difference is a powerful predictor for emotional processing in children and adults, with anxious individuals being hyperactive and avoidant individuals being deactive to emotional stimuli. This study used the event-related potential technique to explore brain responses to facial expressions by adults with anxious, avoidant, or secure attachment–orientation. Differences were found in N1, N2, P2, and N400 components between the groups of participants, suggesting that adults with different attachment–orientations have differences in both earlier, automatic encoding of the structural properties of faces and later, more elaborative retrieval of emotional contents. *NeuroReport* 19:437–441 © 2008 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

The attachment theory is a useful conceptual framework for understanding individual differences in emotional processing and regulation. Bowlby proposed that human beings are born with an innate system which ensures them to seek safety, protection, and support from 'attachment figures' when threatened [1]. On the basis of the observations of infant's responses to separations from and reunions with mother, Ainsworth *et al.* [2] classified infants into one of the three attachment–orientation categories: secure, avoidant, or anxious. Such classification was extended to describe adults' social, emotional, and romantic relationships [3]. It is proposed that attachment–orientation can be assessed in two dimensions: attachment anxiety and attachment avoidance. The secure orientation is low in both anxiety and avoidance, and secure individuals feel comfortable with closeness and interdependence; the anxious orientation scores high in anxiety and low in avoidance, and individuals have strong needs for closeness and relationship; avoidant individuals are high in avoidance and low in anxiety, and they have little attachment security and they keep emotional distance from others [4].

Attachment–orientation affects not only the individual's social behavior to his attachment figures but also his processing and regulation of incoming emotional information that is potentially relevant to attachment concerns [5]. The perception, encoding and recalling of emotional information from the external environment may vary with the orientation [6]. Anxious individuals tend to be hyperactive to affective stimuli. Avoidant individuals prefer to use strategies that limit the processing and retrieving of emotional information. Compared with insecure individuals, secure individuals cope well with stress and can effectively regulate their negative emotional arousal [7,8].

So far, there are few attempts to investigate the neural basis of emotional processing related to adult attachment differences. Using the functional magnetic resonance imaging technique, Gillath *et al.* [9] found that the highly anxious participants of the study showed deactivation in orbitofrontal cortex, a region associated with emotional regulation such as suppression of negative thoughts. Participants high on avoidance showed activation in subcallosal cingulate cortex and lateral prefrontal cortex whereas less avoidant participants showed deactivation in these regions. The authors proposed that anxious individuals may have more difficulty in downregulating negative emotions than nonanxious individuals, and avoidant individuals are less efficient in suppressing negative emotions compared with secure individuals.

Although the above study identified neural processes related to emotional regulation, it has little to say about individual differences in neural processes related to the perception of emotional stimuli. In this study, we used the event-related potential (ERP) technique with a backward-masking paradigm to examine whether and how adults with different attachment–orientations may have differential brain responses to emotional facial expressions. The purpose of using both supraliminal and subliminal presentations of emotional faces was to examine whether the potential differences in brain activation would be modulated by conscious and nonconscious processing [6,9].

Methods

Participants

Participants were 30 male undergraduate students (18–23 years), selected on the basis of their attachment scores from a questionnaire. Ten participants were low in anxiety and avoidance dimensions (i.e. the secure type), 10 were high in anxiety dimension and low in avoidance dimension (i.e. the anxious type), and another 10 were high in avoidance dimension and low in anxiety dimension (i.e. the avoidance type). Participants were healthy, right-handed and none of them had a prior history of neurological or psychiatric disorders. The experiment was approved by the Academic Committee of the Department of Psychology, Peking University.

Questionnaire measures

Five to 6 weeks before the ERP experiment, 243 undergraduate students completed the Experiences in Close Relationships scale. This scale has 18 items on attachment anxiety and 18 items on attachment avoidance. Each item describes an experience, which has to be judged by the participant for the suitability for himself on a 7-point scale ranging from 'not at all' to 'very much'. The reliability and validity of this questionnaire have been repeatedly demonstrated for different cultures, including the Chinese [4,10]. Average scores were 4.85 and 2.69 on the anxiety and the avoidance dimensions, respectively, for the anxious type, 2.80 and 4.69 respectively, for the avoidance type, and 2.31 and 2.76 respectively for the secure type.

Stimuli and design

Three types of facial expressions were selected from a standard Chinese facial expression system. Each type had 30 pictures, from the same persons, with high arousal images for happy and fearful expressions, and for neutral expression. Half of the 30 pictures in each type were from men.

A backward-masking paradigm was used, in which target-mask pairs were presented in two conditions: supraliminal (170 ms SOA, stimulus onset asynchrony) and subliminal (34 ms SOA) [11]. That is, a picture was presented first either for 170 or for 34 ms, followed by a mask presented for 100 ms. Earlier studies have shown that with this short SOA, participants could not report the content of a target face [11]. The mask, a face of another person with neutral expression, moved spatially by a one-degree visual angle in the direction of four diagonals of the target stimulus to avoid artifactual detection of facial expressions by the apparent motion in fear-mask pairs, happy-mask pairs compared with neutral-mask pairs [11]. The same mask was used for all the target faces. Each facial expression from each type was presented five times in each condition.

Participants were first tested with the subliminal presentation, followed by the supraliminal presentation. They were instructed that pairs of target-mask face stimuli would be presented and their task was simply to watch them. It was emphasized that the first face might be difficult to see, but they should concentrate on it as much as possible because they would answer questions about the face after testing. The emotional content of target faces was not revealed in the instruction. Pictures were presented at the center of a computer monitor located approximately 70 cm in front of the participant's eyes.

Electroencephalogram acquisition and analysis

Electroencephalogram (EEG) data were recorded from 64 scalp sites, with reference to the right mastoid and off-line rereferenced to linked mastoids. The horizontal electrooculogram (EOG) was recorded from electrodes at the outer canthus of each eye. The vertical EOG was recorded 1 cm above and below at the left eyes. Electrode impedances were kept below 5 kΩ. The EEG and EOG data were digitized at a sampling rate of 500 Hz. A band-pass of 0.05–100 Hz was used for the recording amplifiers.

The EEG data analysis reported here focused on the midline channels: Fz, Cz and Pz. ERPs were time-locked to the onset of target faces in each condition and were recorded for 200 ms prestimulus until 1000 ms poststimulus onset. The interested ERP components included N1, N2, P2, and N400. Peak amplitudes and peak latencies for different components were found in the following time windows: N1, 50–140 ms; N2, 140–250 ms; P2, 150–250 ms; and N400, 300–600 ms (see Fig. 1).

The N1, N2, and P2 peak amplitudes and latencies were analyzed using analyses of variance, with SOA (34 and 170 ms), emotion (fearful, happy, and neutral), and electrode (Fz, Cz, and Pz) as three within-participant factors, and attachment orientation (secure, anxious, and avoidant) as a between-participant factor. The N400 component was analyzed only for the supraliminal presentation. In all the post-hoc comparisons, the Bonferroni correction was applied where appropriate and only significant results were reported.

Results

The N1 component

For peak amplitude, there was a marginally significant main effect of attachment–orientation [$F(2,27)=3.14$, $P=0.059$]. The avoidant participants showed a less negative N1 ($-4.46\,\mu V$) than the anxious ($-6.32\,\mu V$) and secure participants ($-5.78\,\mu V$). The main effect of emotion was significant [$F(2,54)=3.73$, $P<0.05$], with less negative responses to fearful ($-5.43\,\mu V$) and happy ($-5.43\,\mu V$) expressions than to neutral faces ($-5.71\,\mu V$). The main effect of electrode was significant [$F(2,54)=20.86$, $P<0.001$], with less negativity on Pz than on Fz and Cz. No other effects or interactions were found.

The N2 component

The main effects of emotion [amplitude: $F(2, 54)=3.53$, $P<0.05$; latency: $F(2, 54)=6.41$, $P<0.01$] and SOA [amplitude: $F(1, 27)=46.40$, $P<0.001$; latency: $F(1, 27)=6.38$, $P<0.05$] were significant. Fearful expressions ($-5.49\,\mu V$) had a less negative peak amplitude than neutral and happy expressions (-5.92 and $-5.76\,\mu V$ respectively). Peak latencies for fearful (192 ms) and happy (189 ms) expressions were longer than for the neutral (180 ms). Moreover, the overall amplitude was less negative for supraliminal ($-4.79\,\mu V$) than for subliminal ($-6.66\,\mu V$) presentation, and the peak latency was shorter for the former (179 ms) than for the latter (194 ms). The main effect of electrode was significant [amplitude: $F(2, 54)=49.71$, $P<0.001$; latency, $F(2, 54)=5.36$, $P<0.01$], with less negative amplitudes and shorter latencies on Pz than on Fz and Cz.

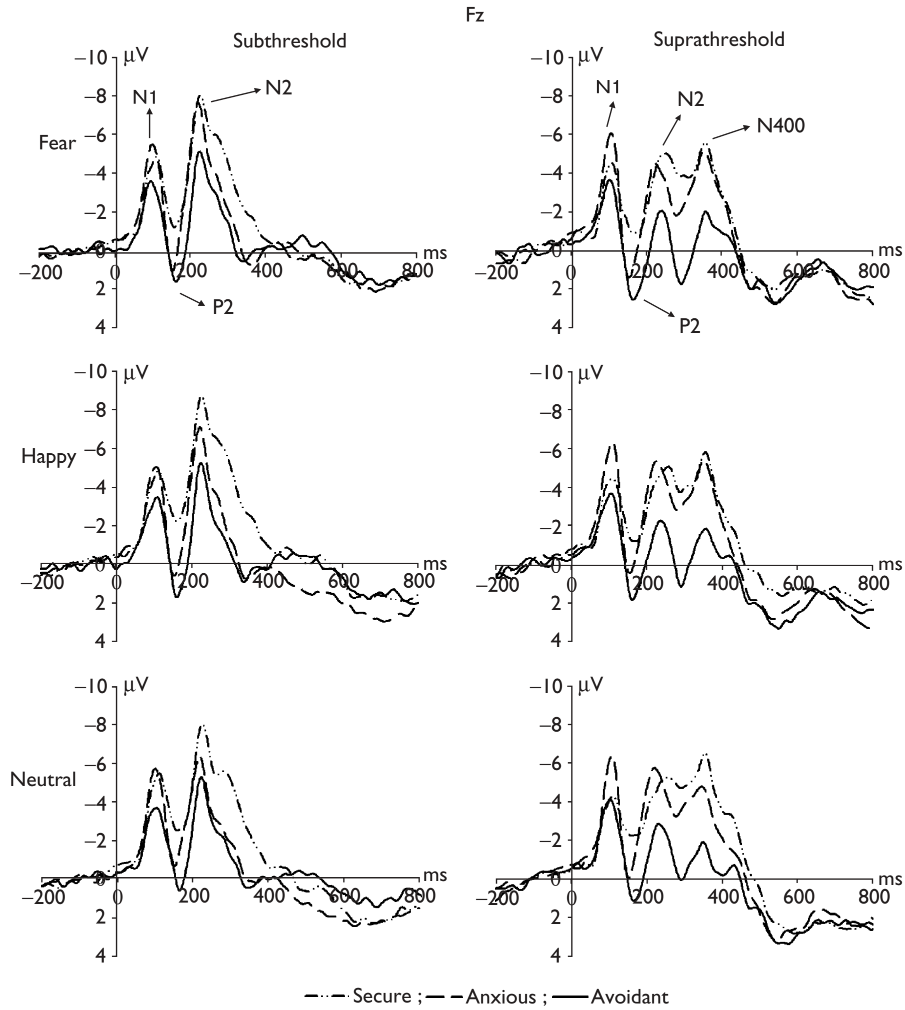

Fig. 1 Event-related potential responses to the subliminal and supraliminal presentation of facial expressions by individuals with different attachment–orientations, clasped over emotional types.

The main effect of attachment-orientation was not significant [F(2,27)=1.31, $P>0.1$], neither the interaction between orientation and emotion [F(4,54)=2.13, $P>0.1$], suggesting that the above patterns of effects were not affected by the orientation type. The interaction between orientation and electrode was, however, significant [F(4,54)=4.39, $P<0.05$]. On Fz, the avoidant participants ($-5.67\,\mu V$) were less negative than the anxious ($-7.87\,\mu V$) and the secure individuals ($-8.59\,\mu V$). The differences on Cz and Pz were not significant ($P>0.1$).

The P2 component

The main effects of emotion [F(2,54)=17.58, $P<0.001$] were significant, with peak amplitude more positive for fearful expression ($3.12\,\mu V$) than for neutral and happy expressions (2.07 and $2.60\,\mu V$, respectively). No effect of latency was found for the emotion type. The main effect of SOA was significant for peak amplitude [F(1,27)=24.70, $P<0.001$] and latency [F(1,27)=10.09, $P<0.01$], with the amplitude more positive for supraliminal ($3.26\,\mu V$) than for subliminal ($1.93\,\mu V$) presentation and the latency longer for supraliminal (176 ms) than for subliminal (167 ms) presentation. The main effect of electrode was significant for amplitude and latency [F(2,54)=30.87, $P<0.001$; F(2, 54)=24.70, $P<0.001$], with more positive amplitude and longer latency on Pz than on Fz and Cz.

The main effect of attachment-orientation was not significant [F(2,27)=1.57, $P>0.1$]. The interaction between orientation and electrode was, however, significant [F(4,54)=5.49, $P=0.001$]. On Fz, the avoidant participants ($3.14\,\mu V$) showed stronger positivity [$P=0.06$] than the anxious ($1.28\,\mu V$) and the secure participants ($0.17\,\mu V$). Similar but not significant ERPs patterns were found on Cz and Pz.

The N400 component

The main effect of emotion was significant [F(2,54)=5.97, $P<0.01$], with less negative N400 peak amplitudes for fearful ($-2.93\,\mu V$) and happy ($-3.03\,\mu V$) expressions than for neutral expressions ($-3.59\,\mu V$). The main effect attachment–orientation was not significant [F(2,27)=2.30, $P>0.1$], but it interacted with electrode [F(4,54)=6.59, $P<0.001$]. On Fz and Cz, the main effect of attachment–orientation was significant [F(2,27)=3.56, $P<0.05$; F(2, 27)=3.45, $P<0.05$], with the avoidant participants showing less negativity (−2.75 and −1.55 μV, respectively) than the secure (−7.33 and −6.43 μV) and the anxious participants (−5.35 and −4.90 μV). The difference between the latter two types did not reach significance.

Discussion

Consistent with earlier studies [12,13], we observed smaller negativities (N1, N2, N400) and larger positivities (P200) for fearful and happy expressions than for neutral expressions. Importantly, we found that avoidant individuals were less negative on N1 and N2 than secure and anxious individuals for both subliminal and supraliminal presentations of faces on posterior (i.e. Pz) and frontal (i.e. Fz) electrodes, respectively, and more positive on P200 on frontal electrodes. Moreover, avoidant individuals showed less negativity than anxious and secure individuals at frontal and middle sites on N400 for supraliminal presentation.

Processing of facial expressions has been proved to consist of two distinct stages: an initial rapid, automatic detection or discrimination of emotionally significant stimuli and a subsequent higher level, conscious processing, including the processing of facial identity and emotional expression [14,15]. The initial processing is reflected in the early (around 100 ms after the stimulus onset), differential ERP responses. In this study, for both subliminal and supraliminal presentations, different facial expressions and different attachment orientations showed distinct N1 responses. Given that N1 is suggested to be an index of the level of attention [16], we may conclude that anxious individuals devote most, and avoidant individuals devote least, attentional resources to face stimuli than secure persons, and these individual differences are the results of automatic processes, applying to both conscious and nonconscious emotional information processing.

Many studies demonstrate that the N2 component reflects structural encoding of faces and the P2 amplitude is modulated by emotional content in face perception [15]. In this experiment, the N2 and P2 effects showed reversed patterns, with smaller N2 and larger P2 amplitudes for fearful expressions than for neutral expressions. Dual-task studies diverting attention away from fearful faces have found that responses in the fusiform face area are reduced and the amygdale activation is maintained. This may reflect the two pathways of facial processing: the facial expression processing and the facial identity processing (i.e. structure encoding, associated semantic information processing) [17,18]. Our results concerning N2 and P2 suggest that the higher emotional arousal (for fearful expressions) reduces the processing of facial structure [19]. Moreover, we found that amplitudes of N2 and P2, at frontal sites, varied according to attachment-orientation. Compared with the secure participants, the avoidant and anxious participants showed less negative N2 and more positive P2, suggesting that they performed less elaborative encoding of the structural information of faces, and they are susceptible to the arousal of emotional content.

Earlier studies also demonstrate that emotionally incongruous faces in paired presentations may elicit larger N400 than congruous expressions [20]. In this study, the congruency effect in N400 did not vary according to attachment–orientation, as we found no interaction between orientation and emotion. The avoidant participants and, to a less extent, the anxious participants did, however, show smaller N400 amplitudes than the secure participants across the emotion types. We interpret the N400 as reflecting high level semantic processing of facial expression, integrating the outputs from expressional and structural processing. Studies in the linguistic domain have shown the magnitude of N400 varies as a function of the easiness of retrieving lexical semantics [21]. As the avoidant participant has spent less attentional resources on the structural encoding of faces, they might have difficulties in retrieving the semantics of faces later on.

Conclusion

Adults with different attachment–orientations show differential brain responses to facial expressions. These differential responses can be found, in ERPs, for both the earlier, automatic structural and expressional processing and later, more elaborative retrieval and integration of semantic contents.

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