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Spatial attention modulates the temporal sequence of hemispheric asymmetry in configural and featural face processing

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ABSTRACT

Face recognition requires both configural and featural processing. Configural face processing is more dependent on the right hemisphere, whereas featural face processing is more dependent on the left hemisphere. The ERP components sensitive to configural and featural face processing were found on P1 and P2, respectively. However, whether lateralized processing is independent of or interacts with the temporal sequence of configural and featural face processing is unclear. To prevent potentially confounding physical stimuli differences between configural and featural face processing from affecting the ERP components, a spatial attention paradigm was employed in which the participants were instructed to attend to the face location (the attended face condition) or the house location (the unattended face condition). The interaction effect of attention, face processing type and hemisphere on the P1 and P2 components indicates that the different mechanisms of configural and featural face processing are a function of spatial attention. Specifically, under the attended face condition, the posterior P1 (approximately 100 ms) for configural face processing was larger than that for featural face processing in the right hemisphere, whereas the P2 (approximately 220 ms) for featural face processing was larger than that for configural face processing in the left hemisphere. In contrast, under the unattended face condition, the P1 for featural face processing was larger than that for configural face processing in the left hemisphere, whereas the P2 for configural face processing was larger than that for featural face processing in the right hemisphere. Therefore, configural and featural processing involve different neural mechanisms, and more importantly, the time course of hemispheric asymmetry in configural and featural face processing is differentially modulated by spatial attention.

1. Introduction

All faces contain the same set of features: a mouth, a nose, and two eyes. These features are arranged equally, with the eyes above the nose, and the nose situated above the mouth. According to the classical theory of face recognition, our ability to discriminate one face from another is based on the ability to perceive the spacing distances among the features and the differences in single features (Bruce and Young, 1986; Le Grand et al., 2001). The former is known as configural face processing or second-order relations, e.g., the distance between the mouth and the nose or between the eyes, and the latter is known as featural face processing, e.g., the shape or color of the eyes or the mouth (Maurer et al., 2002).

Configural and featural face processing are likely processed by different neural mechanisms as shown by neuroimaging (Maurer et al., 2007; Renzi et al., 2013; Rossion et al., 2000), electrophysiological (Scott and Nelson, 2006) and behavioral (Bombari et al., 2014; Cattaneo et al., 2014; Zhang et al., 2015) studies. According to these studies, the right hemisphere is more sensitive to configural face processing than featural face processing, whereas the left hemisphere is more specialized for featural face processing. Using letter-based hierarchical stimuli, researchers have found similar hemispheric lateralization for global and local processing (Fink et al., 1996, 1997a, 1997b). However, other studies have yielded conflicting results. For instance, according to a transcranial magnetic stimulation (TMS) study, the right OFA (occipital face area) plays an important role in early featural face processing (approximately 60 and 100 ms) but not in configural face processing (Pitcher et al., 2007). A behavioral study revealed that configural face information and featural face information are processed by associated mechanisms (Yovel and Kanwisher, 2008). Using object-based hierarchical stimuli, right hemisphere dominance was observed during local processing, and left dominance was observed during global processing (Fink et al., 1997b). Moreover, other neuroimaging and electrophysiological studies using similar face stimuli failed

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to report hemispheric asymmetry in configural and featural face processing in face-selective regions, such as the FFA (fusiform face area; Maurer et al., 2007; Yovel and Kanwisher, 2004) and the N170 component (Wang et al., 2016, 2015; Mercure et al., 2008). Thus, more evidence regarding the hemispheric lateralization of configural and featural face processing is required.

In addition to hemispheric lateralization, the different mechanisms underlying configural and featural face processing involve the temporal sequence. Previous event-related potential (ERP) studies have revealed that several components are sensitive to configural and featural face processing. P1 and P2 components have been shown to be enhanced during configural face processing, and no components were sensitive to featural face processing (Halit et al., 2000; Mercure et al., 2008). However, when the difference waves were computed by subtracting the N170 to the unfamiliar face from that to the familiar face (either configural or featural information), the N170 difference in the right hemisphere was larger for configural face processing than that for featural face processing, whereas the opposite results were observed in the left hemisphere (Scott and Nelson, 2006). Altogether, the P1, P2, and N170 components are potentially sensitive indices for differentiating the brain mechanisms involved in configural and featural face processing. More importantly, a double dissociation was found between configural and featural face processing by comparing the attention effects of configural and featural face processing with the effects of the balanced physical differences of the stimuli (Wang et al., 2016). Specifically, under the attended condition, P1 was more sensitive to configural face processing than to featural face processing (see also Wang et al., 2015), whereas P2 was more sensitive to featural face processing than to configural face processing, but no effect was observed under the unattended condition. Therefore, configural face processing precedes featural face processing, and the time sequence of configural and featural face processing is influenced by attention. Thus far, the relationship between the time sequence and the hemispheric asymmetry in configural and featural face processing and the role of attention in this relationship remain unclear.

To avoid the potentially confounding effects of the physical stimuli, we used a procedure similar to that performed in previous studies (Holmes et al., 2003; Vuilleumier et al., 2001) to manipulate attention; using this procedure, the hemispheric asymmetry in configural and featural face processing and the time sequence variation can be examined as a function of attention. In this study, attention was manipulated by asking the participants to perform a simultaneous same/different matching task based on the cue location. Hemispheric asymmetry has been observed in previous studies employing a sequential same/different face-matching task to investigate featural versus configural face processing (Renzi et al., 2013; Cattaneo et al., 2014; Maurer et al., 2007). Accordingly, we hypothesize that hemispheric asymmetry will be observed in discriminating configural and featural face processing in the current study. Specifically, the right hemisphere activity should be prominent during configural processing, whereas left hemisphere activity is expected to be prominent during featural face processing. Furthermore, because P1 is more sensitive to configural face processing and P2 is more sensitive to featural face processing under the attended condition (Wang et al., 2016, 2015), we predict that the time sequence of the hemisphere asymmetry for configural and featural face processing could also be observed with the P1 and P2 components. More importantly, a significant interaction among attention, face processing type and hemisphere would not only show the dissociation between configural and featural face processing in time sequence and hemispheric asymmetry without the possible confound of physical differences but also reveal the role of attention in this dissociation.

2. Materials and methods

2.1. Participants

Twenty students (9 females and 11 males; 18–26 years old; average age: 21.3 ± 2.4 years) were recruited from Tsinghua University. One participant was excluded from further analysis due to technical issues. The participants were paid for their participation, and all participants were healthy and right-handed and had normal or corrected-to-normal vision. The research protocol was approved by the local Institutional Review Board (IRB) of the Department of Psychology, Tsinghua University. Written informed consent was obtained from each participant prior to the experiment.

2.2. Stimuli and apparatus

The face and house stimuli were the same as those used in our previous study (Wang et al., 2016). Configural face processing was constructed such that the distance between the eyes was either close or far (moving the eye position by 7 pixels (0.25°) inward or outward), and the mouth was either close or far from the nose (moving the mouth position by 7 pixels upward or downward; see Fig. 1**A**). In the featural face processing set, the eyes and mouths were replaced with other eyes or mouths (see Fig. 1**A**). Overall, 12 pictures were presented to assess configural face processing, and 12 different faces were presented to assess featural face processing. The pictures of the 12 different houses were obtained from the Internet (http://image.baidu.com). However, in contrast to the face stimuli, the house stimuli used for the assessment of the configural and featural processing were not manipulated.

All stimuli were presented on a 17-in. ViewSonic monitor (resolution: 1024 × 768; refresh rate: 100 Hz) using E-Prime 2.0 software (Pittsburgh, PA, USA). The viewing distance was 60 cm. The stimulus size was 4° × 5.5° (113 × 156 pixels).

2.3. Procedure

The participants were instructed to maintain fixation on the central cross. The procedure was similar to that performed in previous fMRI and ERP studies (Holmes et al., 2003; Vuilleumier et al., 2001). A trial started with the presentation of a black fixation cross for 500 ms, which was immediately followed by an 80-ms presentation of the attentional cue. The cue instructed the subjects to direct their attention either to the two vertical or two horizontal locations; the stimulus pair at un-

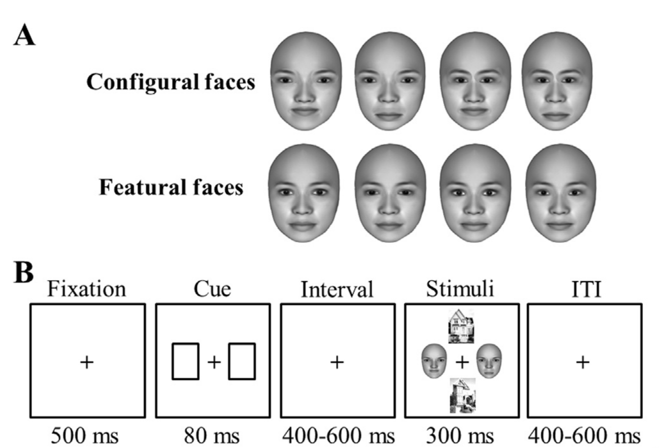

Fig. 1. Illustrations of the stimuli and procedure employed in the study. (A) Illustrations of configural face processing differing in the distance between the eyes or between the mouth and nose. Illustrations of featural face processing differing in the shape of the eyes or month. (B) An illustration of one experimental trial. Participants were instructed to determine whether two cued stimuli were the same or different.