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Research article

Sex differences of hemispheric lateralization for faces and Chinese characters in early perceptual processing

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HIGHLIGHTS

- It investigated sex differences for both face and word processing in same group.
- The N170 amplitude for faces is right lateralized in males and bilateral in females.
- The N170 amplitude for words was bilateral in males and left lateralized in females.
- The N170 latency for faces was faster in females than in males.
- The degree of lateralization of faces was related to that of Chinese characters.

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ABSTRACT

Previous event-related potential studies showed that the N170 response is left-lateralized for words and right-lateralized for faces. Using a one-back repetition task, this study aimed to clarify sex differences in hemispheric specialization for both faces and words in early visual processing. We found that the N170 amplitude elicited by faces in males was right-lateralized, while in females it was bilateral. Interestingly, the N170 amplitude elicited by Chinese characters in males was bilateral, whereas in females it was left-lateralized. The N170 latency for faces was shorter in females than in males, whereas the N170 latency for Chinese characters was similar in females and males. The degree of lateralization of faces was significantly related to the degree of lateralization of Chinese characters in both the female and male groups. Therefore, sex differences in N170 hemispheric lateralization for faces are different from those for Chinese characters, and there are some links between the two categories of objects of expertise in early perceptual processing.

1. Introduction

Studies of event-related potentials show that the specific N170 response has become a stable electrophysiological hallmark of objects related to expertise in early perceptual processing. Understanding the characteristics of the N170 component involved in processing faces and nonface objects of expertise is important for the investigation of early perceptual mechanisms. Researchers have suggested that there is a special neural response involved in the perception of faces. In event-related potential (ERP) studies, the N170 response elicited by faces is often larger than that elicited by non-face objects [1–4]. Words are highly familiar nonface objects of expertise. Previous studies have found that the N170 component evoked by words is much stronger than that elicited by other stimuli, such as letter strings [5,6] or line drawings [7–11].

Recently, researchers have focused on the sex differences in the neural response elicited by objects of expertise [12–15]. For instance, Guillem and Mograss showed that ERP amplitudes are generally larger in females than in males for the N300 and N400 components in face processing [16]. Importantly, regarding early perceptual processing, previous studies have consistently found a much larger face-specific N170 response in the right hemisphere in males, and a bilateral response in females [13–15,17–19]. Very few studies have used ERP to explore sex differences in word processing and these have shown mixed results; some [20,21] reported differences between males and females, while others found no sex differences [22]. Particularly, the ERP results in tasks examining the early stages of word processing were mixed [21,22].

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The studies noted above show sex differences in the N170 component for face processing, whereas the results are inconsistent for word processing. Based on the reviewed literature, the present study followed two aims: First, as words are highly familiar nonface objects of expertise, in order to promote a better understanding of expertise processing, we aim to address the sex differences of the N170 component for word recognition. Therefore, we chose a one-back repetition paradigm to reveal the sex differences of the N170 component for word processing. Second, recent studies have suggested that there are many links between face and word processing [23–25]. For example, the face-response displacement effect: as literacy increases, face-induced functional magnetic resonance imaging (fMRI) responses in the left fusiform face area (FFA) become slightly smaller but increase substantially in the classical right FFA [26]. This effect was replicated in an fMRI study on children [27] and ERP studies on children and adults [28,29]. Moreover, there were some overlaps of neural selectivity between faces and words in early perceptual processing [30]. Additionally, face recognition impairments were more severe following bilateral than unilateral lesions [31] and a left occipital arteriovenous malformation resulted in both pure alexia and prosopagnosia [32]. However, previous studies were designed to examine the sex differences of the N170 component for faces or words separately. As such, the links of the sex differences of the N170 response in face and word processing in the same participant is still unclear. Therefore, we aimed to examine the links of the sex differences in the N170 response elicited by both faces and words. We chose long-term objects of expertise (face and word) as stimuli, and line drawing, a familiar object of non-expertise, as control stimulus. Given the existing evidence of sex differences for face [13–15,17–19] and word processing [20,21], but see [22], we expected to replicate these sex differences for hemispheric lateralization of faces and address sex differences for Chinese characters. As noted above the links between faces and words, we also expected to find that the degree of hemispheric lateralization of Chinese characters would be significantly related to the degree of hemispheric lateralization of faces.

2. Materials and method

2.1. Participants

Eighty-four right-handed [33] volunteers (42 females) were recruited from local universities and were paid for their participation (age range 18–25 years, mean 21.6 years). All participants had normal or corrected-to-normal vision and reported to be free from any current or past neurological or psychiatric diseases. The study was approved by the ethical committee of Zhejiang Normal University and was carried out in accordance with the approved guidelines. Written consent was obtained from all participants. None of the participants were familiar with the experimental design of the study.

2.2. Stimuli

Grayscale pictures of faces, Chinese characters, and line drawings were used in this experiment, with 30 pictures of each type. Thirty faces (15 males and 15 females) were selected from a standard set of faces from our laboratory. Each face had a neutral expression. They were cropped to remove external features (hair, ears, and jaw line) and replaced with the same oval contour using Adobe Photoshop CS5 (San Jose, CA). The face stimuli were 180×276 pixels, subtending an angle of $4.0^\circ \times 6.2^\circ$. Chinese characters with a left-right configuration were chosen from the Modern Chinese frequency dictionary [34]. All were high-frequency characters, with the number of strokes varying from 7 to 14. They were presented in Song font. The Chinese characters were 198×198 pixels, subtending an angle of $4.5^\circ \times 4.5^\circ$. The line drawings were used as control stimuli. They were taken from the Snodgrass picture set [35]. The line drawings were 137×199 pixels, subtending an angle of $3.0^\circ \times 4.5^\circ$.

2.3. Procedure

Participants were required to sit at a distance of 90 cm from the 17″ cathode ray tube monitor (1024×768 pixel resolution) on which all stimuli were presented against a dark gray background. The E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA) was used for stimuli presentation and behavioral response collection. The faces, Chinese characters, and line drawings were shown in the center of the screen. The 72 stimuli of each category were shown in three blocks randomly containing 17% immediate repetitions, serving as targets in the task. Each category had 12 target trials. The participants were asked to press a mouse button with their preferred hand after an immediate stimulus repetition. The stimulus duration was 200 ms, followed by a 1900 ms (random 1700–2100) inter-stimulus interval.

2.4. Electroencephalogram recording and data analysis

An electroencephalogram (EEG) was recorded using a 128-channel HydroCel Geodesic Sensor Net (Electrical Geodesics, Inc., Eugene, OR), with an electrode placed on the vertex (Cz) serving as reference for the online recording. Electrode impedances were kept below 50 kΩ. Signals were digitized at a 500 Hz sampling rate and amplified with a 0.1–200 Hz elliptical bandpass filter. The EEG data were digitally filtered offline with a 0.3–30 Hz band-pass filter and epoched from 200 ms before to 800 ms after stimulus onset with a 100 ms pre-stimulus baseline. Trials with artifacts exceeding $\pm 100\,\mu V$ were rejected. Trials were also removed from ERP averaging if they contained eye movements (greater than $\pm 70\,\mu V$). After incorrect trials and trials containing movement artifacts were eliminated, any participant with more than 30% bad segments was excluded from the group average. A minimum of 50 good trials in each stimulus category was required to retain a participant for the analyses. Four participants (two males) were excluded from the analyses. The remaining EEG data were re-referenced to the average of the channels.

The EEG data were analyzed for non-response trials only. A group of channels over the left occipitotemporal regions (O1, 65, T5; channel 65 in the middle between O1 and T5) and right occipitotemporal regions (O2, 90, T6; channel 90 in the middle between O2 and T6) was analyzed where the N170 components were maximal [30]. In order to reduce the number of levels in the statistical analyses, these peak amplitudes and latencies were then averaged across the three channels chosen for each hemisphere. The EEG waveforms were averaged separately for each presentation condition. Based on visual inspection of the individual data, the N170 time window was defined as 130–210 ms after stimulus onset. The N170 responses were analyzed in a repeated measures multivariate analysis of variance (MANOVA) for stimulus category (faces, Chinese characters, line drawings), sex (male, female), and hemisphere (left, right). Main effects and interactions were family-wise Bonferroni corrected to take into account the adjustment of the alpha level. The corrected threshold for significance was $0.05/7 = 0.0071$. Bonferroni correction to alpha levels was also used for the post hoc analysis. We used *t*-tests to analyze the N170 response in the left and right hemisphere during the processing of faces, Chinese characters, and line drawings in both participant groups. In addition, we analyzed the correlation of the hemispheric lateralization between