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Electrophysiological evidence for women superiority on unfamiliar face processing

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ABSTRACT

Previous research has reported that women superiority on face recognition tasks, taking sex difference in accuracy rates as major evidence. By appropriately modifying experimental tasks and examining reaction time as behavioral measure, it was possible to explore which stage of face processing contributes to womens' superiority. We used a modified delayed matching-to-sample task to investigate the time course characteristics of face recognition by ERP, for both men and women. In each trial, participants matched successively presented faces to samples (target faces) by key pressing. It was revealed that women were more accurate and faster than men on the task. ERP results showed that compared to men, women had shorter peak latencies of early components P100 and N170, as well as larger mean amplitude of the late positive component P300. Correlations between P300 mean amplitudes and RTs were found for both sexes. Besides, reaction times of women but not men were positively correlated with N170 latencies. In general, we provided further evidence for women superiority on face recognition in both behavioral and neural aspects.

1. Introduction

Human faces are special stimuli with ecological salience. People can distinguish faces from many similar things quickly and accurately. Proper processing of faces is particularly important for interpersonal communications since faces convey a large amount of social information including details of race, age, gender and emotion, which would help us take appropriate mode of actions. Face recognition is one of the most nature techniques for identifying human beings. It involves perceptual and cognitive processes when people recognize faces. A large amount of literature on face recognition has focused on how people could identify whether a face has been seen before (Bengner et al., 2006; Lewin and Herlitz, 2002; Rehnman and Herlitz, 2006; Rehnman and Herlitz, 2007; Vokey and Read, 1988). An interesting fact has been revealed, that women often outperformed men in such tasks (Brewster et al., 2011; Cross et al., 1971; Ellis et al., 1973; Lewin and Herlitz, 2002; McBain, Norton and Chen, 2009; McKelvie, 1981; Megreya et al., 2011; Rehnman and Herlitz, 2006; Rehnman and Herlitz, 2007; Vokey and Read, 1988). Also, previous research showed that women superiority on face recognition was robust enough to survive brain diseases such as temporal lobe epilepsy or general epilepsy (Bengner et al., 2006).

Most behavioral studies concerning women superiority in face recognition took use of a learning-test paradigm. During a typical experiment, a serial list of unfamiliar faces was displayed for few seconds each, and participants were instructed to memorize these faces carefully, as they had to recognize them from unseen faces later. In such studies, women superiority in face recognition was consistently represented by their higher accuracy compared to men (Bengner et al., 2006; Cross et al., 1971; Ellis et al., 1973; Lewin and Herlitz, 2002; McBain et al., 2009; McKelvie, 1981; Megreya et al., 2011; Brewster et al., 2011; Rehnman and Herlitz, 2006; Rehnman and Herlitz, 2007; Vokey and Read, 1988). Furthermore, other researchers employed a masked priming paradigm to investigate sex difference on face recognition tasks. In this paradigm, a masking stimulus was presented after priming stimuli, to explore whether the prime would affect the response to target even when priming stimuli were unconscious. The results revealed that women made significantly quicker response towards faces than men did (Godard and Fiori, 2010). Taken together, previous research has confirmed

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that not only were women more accurate than men in face recognition tasks, but also did they process face stimuli much faster than men did. It would be reasonable, then, to raise the question that in which specific stage(s) of face process women outperform men. However, few studies have tried to explore the issue.

According to the functional model of face recognition proposed by Bruce and Young, face recognition was carried out by steps (Bruce and Young, 1986). In this model, the process of face recognition was divided into three stages. Face was structurally encoded first, then information got into two independent pathways (visual process pathway and face recognition pathway) for processing, finally, information was integrated and decision was made in the cognitive system.

The Bruce-Young model provided a theoretical basis for investigating the process of face recognition. As a high temporal resolution instrument, event-related potential (ERP) provided a reliable reference to separate the processing stages of face recognition. ERPs recorded from the brain should give us important information of neural mechanisms under face processing. As to visual stimuli, ERPs to faces involved an early positive component over occipital (P100) peaking about 100 ms after face pictures onset. P100 was considered a sign of early visual processing (Schendan et al., 1998). It has also been displayed to be sensitive to participants' state of arousal (Vogel and Luck, 2000). The most intensively focused ERP component in face recognition is N170 (Bentin et al., 1996; Dalrymple et al., 2011; Eimer, 1998; Eimer, 2000; Zion-Golumbic and Bentin, 2007), which is a negative component recorded from the bilateral occipito-temporal scalp with its peak at about 170 ms from stimulus onset. Amplitudes of N170 are usually larger for faces than non-face objects (Ganis et al., 2012; Itier and Taylor, 2002; Joyce and Rossion, 2005; Kovács et al., 2006; Schendan et al., 1998). The N170 component is thought to reflect the processing of structure encoding stage in Bruce-Young model of face recognition (Bentin et al., 1996; Eimer, 2000; Itier and Taylor, 2004; Latinus and Taylor, 2006; Rossion and Jacques, 2008). N170 is sensitive to the difficulty in structure encoding of face stimuli. For example, both amplitude and latency of N170 increase when processing inverted faces compared to upright faces (Rossion et al., 1999). Moreover, researchers also found that N170 showed a hemispheric asymmetry, and the peak amplitudes of the occipito-temporal N170 were larger in the right hemisphere than in the left (Proverbio et al., 2006).

Another important ERP component that might be related to face recognition is long-latency P300. P300 is evoked when participants have to detect a stimulus, such as those in the paradigm which is named as "oddball" (Verleger, 1988). In such an experimental design, low-frequency target is mixed with high-frequency standard stimuli. The P300 component is thought to reflect attention resource allocation, working memory updating and decision-making (Linden, 2005).

It is worth noting that, many previous research discussing sex difference in face recognition took use of a classical study-test paradigm, which required participants learn much more faces than their maximum capacity of working memory for faces (2 faces, see Morgan et al., 2008). As a result, learned faces may interfere with each other. Besides, sex difference revealed by study-test paradigm might be contaminated by women's better episodic memory, rather than their superiority in face recognition. In the current study, we studied women superiority in face recognition with an oddball paradigm and a modified delayed match-to-sample working memory task (Jiang et al., 2000), in which participants processed unfamiliar faces on-line. In order to eliminate external interference to the greatest degree, we modified the face-processing task to keep participant's working memory at its highest load (Morgan et al., 2008). Specifically, the sample target presented at the beginning of every trial was composed of two faces of different sex presented side-by-side on the screen. Following that, nine male or female faces were displayed at the center of the screen consecutively. Participants decided whether each face was identical to one of the faces in the sample target. We recorded both reaction time (RT) and accuracy as indicators of women superiority. At the same time, ERP evoked by the faces were recorded. We compared different ERP components of men to those of women observers, and thus to explore in which stage of face recognition that women outperform men. Our focus was on the face recognition specific temporal N170 component that had been found to correlated with activations in the face perception neural network (i.e., temporal-occipital "core", Sadeh et al., 2010), and the occipital P100 component that was related to early rapid processing (Hopf and Mangun, 2000; Martınez et al., 2001). Furthermore, the late positive component P300 reflecting the intensity of the cognitive processes (García-Larrea and Cézanne-Bert, 1998; Polich, 2007; Steiner et al., 2013) was also addressed. We predicted that women would outperform men on face recognition tasks. In addition, this superiority of women should be found on not only a behavioral but also a neural level. Furthermore, we expected that the behavioral performances were correlated to some of ERP components. In order to ensure women superiority in the current delayed matched-to-sample task was specific to face recognition, we ran a control task following the same procedure but with line drawings as stimuli (Snodgrass and Vanderwart, 1980). We predicted no sex difference to be found in the control task.

2. Materials and methods

2.1. Participants

Thirty-two Chinese college students (16 men and 16 women) participated in a face-recognition task and received monetary remuneration. Since age had been proved to affect face recognition (Boutet et al., 2015), male and female participants were matched on age (for men, mean age = 20.56 ± 0.96 years; for women, mean age = 20.82 ± 0.75 years, an independent samples t-test revealed no significant difference between genders, $t_{(30)} = 0.819$, $p = 0.419$).

Forty college students (20 men and 20 women) participated in a control task and received monetary remuneration. Their ages were matched between genders (for men, mean age = 19.70 ± 1.03 years; for women, mean age = 19.40 ± 0.82 years, an independent samples t-test revealed no significant difference between genders, $t_{(38)} = 1.013$, $p = 0.315$).

All participants were right-handed heterosexuals, with normal or corrected-to-normal vision. None of them reported history of psychiatric diagnoses. Informed consent was acquired prior to the experiment. This research was approved by East China Normal University Ethics Committee.

2.2. Materials

Stimuli were face photographs including external features, e.g. hair and ears (Boehm et al., 2011; Fales et al., 2010; Gur et al., 2002; Platek et al., 2006; Proverbio et al., 2006; Taylor et al., 2009; Weirich et al., 2011; Wirsich et al., 2014). In total, 320 colored face photos of young people (half male and half female) were used in the experiment. All photos were in frontal view, with a neutral facial expression and no obvious signs (such as beard, glasses, cutaneous nevus, and face painting). Luminance and contrast levels of all face photos were controlled after being modified eliminating unique contrast using Photoshop CS4. All photos were 8.3 cm in heights and 5.4 cm in widths. And none of them has been seen by participants before. 80 out of 320 face photos (40 male and 40 female faces) were used as target stimuli and the other 240 photos were used as distractors.