Neuroscience 328 (2016) 194–200

GENDER DIFFERENCES IN VENTROMEDIAL PREFRONTAL CORTEX ACTIVITY ASSOCIATED WITH VALUATION OF FACES

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Abstract—Psychological studies have indicated that males exhibit stronger preferences for physical attributes in the opposite gender, such as facial attractiveness, than females. However, whether gender differences in mate preference originate from differential brain activity remains unclear. Using functional magnetic resonance imaging (fMRI), we investigated the patterns of brain activity in the ventromedial prefrontal cortex (vmPFC), a region critical for the valuation of faces, in response to elderly male, elderly female, young male, and young female faces. During fMRI, male and female subjects were presented with a face and asked to rate its pleasantness. Following fMRI, the subjects were presented with pairs of faces and asked to select the face that they preferred. We analyzed the vmPFC activity during the pleasantness-rating task according to the gender of the face stimulus (male and female) and the age of the face stimulus (elderly and young). Consistent with the results of previous studies, the vmPFC activity parametrically coded the subjective value of faces. Importantly, the vmPFC activity was sensitive to physical attributes, such as the youthfulness and gender of the faces, only in the male subjects. These findings provide a possible neural explanation for gender differences in mate preference.

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Abbreviations: BOLD, blood oxygenation level-dependent; EPI, echo planar imaging; fMRI, functional magnetic resonance imaging; FOV, field of view; MRI, magnetic resonance imaging; ROI, region-of-interest; vmPFC, ventromedial prefrontal cortex.

http://dx.doi.org/10.1016/j.neuroscience.2016.04.047
0306-4522/

Key words: value, face, gender difference, ventromedial prefrontal cortex, functional MRI.

INTRODUCTION

Following Darwin's proposal of sexual selection as a driving force in evolution, evolutionary biologists and psychologists have generated considerable evidence of gender differences in human mate preference (Hill, 1945; Buss and Barnes, 1986; Buss and Schmitt, 1993; Sprecher et al., 1994; Buss et al., 2001; Rhodes, 2006; Todd et al., 2007). Females place more value on attributes such as social status, financial status, and ambition, whereas males place more value on physical attributes, such as physical attractiveness, youthfulness, and health (Buss and Barnes, 1986; Todd et al., 2007). These tendencies are apparent across cultures and are invariant across decades (Buss, 1989; Buss et al., 2001). Considerable literature supports the theory of parental investment, which states that females seek fewer opposite-gender encounters than males, whereas males seek more opposite-gender encounters than females (Trivers, 1972; Buston and Emlen, 2003). Consistent with this notion, a recent psychological study of a speed-dating event demonstrated that females were more discriminating than males and exhibited a lower tendency to choose a man as a mate (Todd et al., 2007). Thus, females and males are likely to employ different strategies for mate preference to achieve reproductive success.

These psychological findings demonstrate differences in mate preference between males and females; however, less is known regarding the neural mechanisms that underlie these gender differences. Several studies have demonstrated that reward-related brain areas, including the ventral striatum and the ventromedial prefrontal cortex (vmPFC), are involved in the evaluation of faces (O'Doherty et al., 2003; Kranz and Ishai, 2006; Cloutier et al., 2008; Lebreton et al., 2009). Thus, it is reasonable to postulate that the patterns of brain activity in these regions differ between males and females in response to facial stimuli. Previous studies using functional magnetic resonance imaging (fMRI) have addressed this question. For example, O'Doherty et al. reported increased vmPFC activity in response to attractive faces of the opposite gender in males compared to females (O'Doherty et al., 2003). Cloutier et al. reported that the vmPFC activity differentiated attractive faces from unattractive faces in males but not in females (Cloutier et al., 2008). These studies have raised the possibility that among the reward-related brain regions, the vmPFC is a key region involved in gender differences in mate preference.

Although these previous studies have examined gender differences in vmPFC activity in response to facial attractiveness, it remains unclear which aspects of facial information are processed in the vmPFC in males and females. If the vmPFC activity in males is more sensitive to biologically important targets for reproductive success than in females, the vmPFC activity is expected to specifically increase only in males in response to young faces of the opposite gender. To address this issue, we used the faces of elderly males, elderly females, young males, and young females as experimental stimuli, which enabled us to systematically investigate whether the vmPFC exhibits differential sensitivity to the age and gender of facial stimuli between male and female subjects. We predicted that the vmPFC activity in males would be more sensitive to the gender and age of the facial stimuli.

EXPERIMENTAL PROCEDURES

Subjects

Thirty-three healthy, young volunteers (17 females and 16 males; age range, 20–25 years; mean age, 21.2 years) with no history of neurological or psychiatric disease participated in this study. No pathological findings in the brains of the participants were identified using magnetic resonance imaging (MRI). All subjects were right-handed as assessed using the Edinburgh Handedness Inventory (Oldfield, 1971) and had normal or corrected-to-normal vision. After the subjects received a detailed description of the study, they provided their written informed consent in accordance with the Declaration of Helsinki, and the guidelines were approved by the Ethical Committee of Tohoku University. The data from one female participant were excluded from the analysis because she indicated that she was a lesbian after the experiment. Thus, the present results are based on data from the remaining 32 heterosexual participants (16 females and 16 males; age range, 20–25 years; mean age 21.3 years). There was no significant difference in age ($t(30) = 1.059$, $p = 0.302$) between the female and male subjects.

Stimuli

Sixty-four elderly male (age range, 61–79; mean age, 71.4 years), 64 elderly female (age range, 62–79; mean age, 69.1 years), 64 young male (age range, 20–28; mean age, 22.2 years), and 64 young female (age range, 20–28; mean age, 21.8 years) volunteers were recruited to pose for facial photographs. They were informed that the photographs would be used for research purposes only, and they provided written informed consent. The photographs were captured using a Panasonic DMC-LX2 digital camera with a flash and a resolution of 1920×1080 pixels. The photographed individuals were asked to present a neutral facial expression and to look directly into the camera. All images were subsequently downloaded onto a computer and edited in Adobe Photoshop CS5.1 and Adobe Illustrator CS5.1 (San Jose, CA, USA) to produce greater uniformity across the photographs; they were also resized to 720×540 pixels. A separate group of 13 young volunteers (7 females and 6 males; age range, 18–25 years; mean age, 20.2 years), who did not participate in the fMRI study, rated the 256 facial photographs using a 10-point scale for pleasantness. The mean pleasantness score was ranked within the four stimulus groups (i.e., elderly male, elderly female, young male, and young female). Within each stimulus group, the photographs ranked "n" (n = 1–32) were paired with the photographs ranked "$n + 32$", which resulted in 32 pairs of photographs per group.

Experimental design

The experiment consisted of two tasks: a pleasantness-rating task during fMRI and a choice task after fMRI (Fig. 1). For the pleasantness-rating task during the fMRI scan, each of the 256 face photographs was presented in a random order (Fig. 1a). Each stimulus was presented for 2.5 s, and the inter-stimulus interval, during which the cross-fixation was constantly presented, ranged between 3.5 and 11.5 s to maximize the efficiency of the event-related design (Dale, 1999). The pleasantness-rating task was divided into four consecutive runs, each lasting approximately 10 min. The subjects were asked to rate each face based on how pleasant or unpleasant it was using a 5-point scale. The response device had five buttons, each corresponding to the thumb, index, middle, ring, or little fingers of the right hand. The responses were counterbalanced with a Likert-scale direction (1 = very unpleasant and 5 = very pleasant or vice versa).

The choice task was performed outside the scanner immediately after the fMRI (Fig. 1b). The 128 pairs of photographs were displayed as two side-by-side photographs, and the subjects were asked to select the face that they preferred by pressing one of two buttons. As previously described, the face stimulus that was ranked "n" was paired with the face stimulus that was ranked "$n + 32$." Furthermore, the combinations of two photographs selected for presentation as pairs were fixed; however, the order of the presentation of the pairs was randomized across the subjects. The positions (right or left) of the two photographs within the pairs were counterbalanced across the subjects.

Image acquisition

Whole-brain imaging was performed using a 3.0-tesla MRI scanner (MAGNETOM Trio, A Tim System; Siemens-Asahi Medical Technologies Ltd., Tokyo) equipped with a 12-channel head coil array for signal reception. A $T2^*$-weighted echo planar imaging (EPI) sequence sensitive to blood oxygenation level-dependent (BOLD) contrast was used for functional imaging with the following parameters: repetition time (TR) = 2,500 ms, echo time (TE) = 30 ms, flip angle = 90°, acquisition matrix = 80×80, field of view (FOV) = 240 mm, in-plane resolution = 3×3 mm,