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Short communication

Gender difference in hemodynamic responses of prefrontal area to emotional stress by near-infrared spectroscopy

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Abstract

Presentation of negative pictures was used as emotional stress to assess gender differences in prefrontal area activation in a functional near-infrared spectroscopy (NIRS) study. Compared with neutral condition, the response of oxy-HB for men yielded no significant difference during stress period, but the response induced by stress pictures for women showed significant enhancement. It was indicated that it is crucial to take gender difference into account when negative stimuli are used in functional brain imaging.

Keywords: Prefrontal cortex activation; Near-infrared spectroscopy; Emotional stress

Stress research has been a long and fruitful line since the initial investigations. An important issue on stress is to establish whether stress response patterns differ between male and female subjects because information about sex-related characteristics in the processing of stress stimuli is essential to understand the mechanisms underlying the gender-related vulnerability of certain neuropsychiatric disorders such as mood disorders [1]. Many studies have investigated whether gender differences exist in tasks of emotional processes. However, the result on sex-related differences during emotional stress was not conclusive. It was reported in brain imaging studies that healthy women displayed more activity than healthy men in the inferior frontal, orbital and prefrontal cortices during transient induced sadness [2], whereas it had ever been reported that processing of sadness was more focal and subcortical in men [3]. In addition, gender differences in IAPS images in terms of subjective ratings and physiological response were reported, indicating congruence was displayed between the two genders when viewing pictures [4], while other studies indicated that gender differences of brain activity do exist for emotional visual stimuli [5] although no significant differences were found between males and females in valence and arousal.

It should be noted that many problems arise when attempting to compare related studies on the investigation of gender differences in emotional stress reactions. First, a variety of different emotional stimuli materials used in brain imaging studies, such as human emotional nonverbal sounds [6], facial affect [7], emotional words [8], were not standardized and comparable. Second, most studies of emotion have examined the role of affective materials within the context of behavioral response tasks, such as stimulus ratings, stimulus discrimination, or target detection. Therefore confounding response to behavior and cognitive task overwhelmed the changes to the negative stimuli [9].

Prefrontal locations were suggested to be closely associated with emotional stress and negative emotional reactions [10]. Because NIRS can detect the oxygenation of prefrontal area in brain tissue, it has been developed into a useful tool for functional mapping of human brain activity [11]. In contrast to visible light, light from near-infrared spectrum (700–1000 nm wave length) can penetrate skull and is absorbed mainly by oxygenated hemoglobin (oxy-HB) and deoxygenated hemoglobin (deoxy-HB) which have different absorption spectra. Concentrations of oxy-HB and deoxy-HB in living brain tissue can theoretically be calculated from the amount of absorbed near-infrared light [12]. With this technique, the successive real-time changes in cere-

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bral oxygenation and hemodynamics accompanying neuronal activity can be observed because of its high temporal resolution. Simultaneous measurements with NIRS and other techniques, such as positron emission tomography (PET), have confirmed its reliability in estimating cerebral blood flow [13]. Therefore brain hemodynamic reaction as detected by NIRS will be a stable and objective index in contrast to the data of ratings and behavior.

In this study, we set out to assess prefrontal hemodynamic activation in healthy male and female college students with NIRS during presentation of negative versus neutral pictures taken from the International Affective Picture System (IAPS), which is a standardized method to evoke and assess emotions with respect to arousal and valence [14]. In the experimental session, no behavioral response to stimuli was requested of the participants in order to reduce hemodynamic response to behavioral and cognitive task. The aim of this study was to investigate the relationship between sex and prefrontal hemodynamic response induced by emotional stress.

Thirty right-handed paid volunteers (11 males and 19 females, 22–32 years old) with normal or corrected-to-normal vision, consisting of comparable ages (mean [S.D.]: $24.27 \pm 1.56/24.42 \pm 2.29$; $t_{28} = 0.19$, $P > 0.05$) and education (mean [S.D.]: $17.73 \pm 0.90/17.63 \pm 0.07$; $t_{28} = 0.25$, $P > 0.05$) participated in this study. A brief medical screening interview was used to exclude subjects with any physical or neurological illness or medication affecting neural function. Psychiatric illnesses were excluded by using Symptom Check List-90 (SCL-90) [15]. Prior to each study, written informed consent was obtained from all participants.

Pictures of International Affective Pictures System (IAPS) were used as emotional stress materials [14]. The pictures were arranged in two sets: a neutral set of pictures (household objects) and a negative set of pictures (mutilated bodies or bloody and accident situations). The IAPS ratings expressed as valence and arousal was 4.2 and 2.5 for the neutral set, 2.1 and 6.7 for the negative set. Before experiment session, these pictures were re-assessed by another 30 college students (11 males and 19 females, 22–28 years old) who are recruited from the same population of comparable age (mean [S.D.]: $24.18 \pm 1.40/23.47 \pm 1.93$; $t_{28} = 1.06$, $P > 0.05$) and education (mean [S.D.]: $17.27 \pm 0.65/16.58 \pm 1.26$; $t_{28} = 1.69$, $P > 0.05$). The two sets of pictures were rated in terms of valence and arousal, the two primary dimensions of emotion. The difference in the mean rating of valence and arousal between negative and neutral pictures was significant for males (valence: $2.09 \pm 0.54/5.03 \pm 0.16$, $t_{20} = 17.36$, $P < 0.01$; arousal: $7.09 \pm 1.15/3.02 \pm 1.37$; $t_{20} = 7.59$, $P < 0.01$) and females (valence: $1.85 \pm 0.63/4.77 \pm 0.79$, $t_{36} = 12.55$, $P < 0.01$; arousal: $7.34 \pm 0.92/2.47 \pm 0.94$; $t_{36} = 16.15$, $P < 0.01$) separately, whereas the difference of rating was not significant between males and females. The final materials contained 40 pictures: 20 stress pictures and 20 neutral control pictures. Negative pictures were slides 2053, 2205, 2750, 2800, 3015, 3051, 3061, 3062, 3100, 3160, 3168, 3181, 3230, 3261, 3301, 3350, 3550, 9040, 9140 and 9432. Neutral pictures consisted of IAPS slides 5535, 7002, 7004, 7006, 7009, 7010, 7020, 7025, 7030, 7031, 7035, 7040, 7050, 7080, 7100, 7150, 7175, 7217, 7705 and 7950.

During emotional stress the two sets of pictures were presented in two experimental conditions. For one experimental condition, subjects were presented with neutral pictures. In the other condition, subjects were presented with stress pictures. Subjects were instructed to watch them carefully and need not do any responses with hands. Each picture was presented for 5 s, and each experimental condition included 20 stimuli. The paradigm involved two 30 s baseline periods alternating with two 100 s tasks periods. During baseline period the subjects were passive viewing "+" for 30 s. The order of pictures for the two sets was pseudorandom, and the experimental order was counterbalanced across subjects. All participants were given practice with the tasks before NIRS experimental session.

Oxy-HB changes in the prefrontal area were measured using a 16-channel NIRS system [16] (The Key Laboratory of Biomedical Photonics of Ministry of Education, Huazhong University of Science and Technology in China). The imager included four three-wavelength (735, 805, and 850 nm) light emitters and ten detectors. All optodes were attached with a soft rubber pad and further fixed with an elastic band. The measurement covered an area of 18.6 cm × 7.4 cm centred over electrode position FPz, and was localized symmetrically and mainly over the prefrontal cortex (see Fig. 1). The distance between pairs of emission and detector probes was set at 2.89 cm, which enabled cerebral blood volume measurements at a 2–3 cm depth from the skin of the head, that is, the surface of cerebral cortices [17]. The detector's output signal, which was proportional to light intensity, was amplified and then inputted into the computer through an A/D board. The light intensity changes in wavelength of 735, 805 and 850 nm can be calculated by the software attached to the 16-channel NIRS system and then converted to concentration changes of oxy-HB using modified Beer–Lambert Law [18].

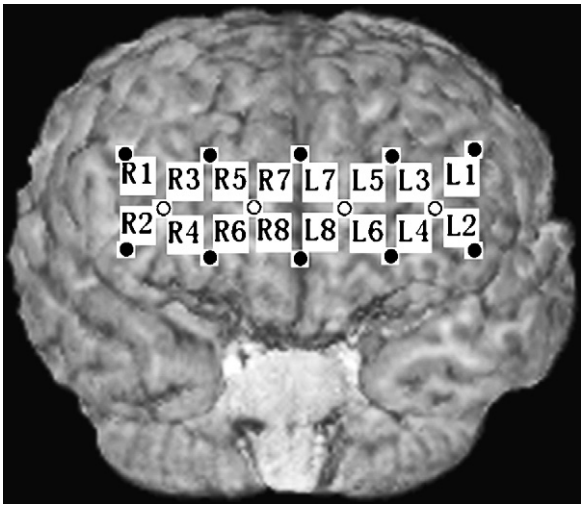

Fig. 1. NIRS channel orientation. Illuminators are shown as white circles, detectors as black circles and channels as white squares. One holder with eight NIRS channels (channels L1–L8) was set on the left side of a subject, and the other eight channels (channels R1–R8) were placed on the right side in a similar manner, so that the midpoint of channels L7, R7, L8 and R8 fits the Fpz of the international 10–10 system.