Research Report

Self-Construal Priming Modulates Neural Substrates of Self-Awareness

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ABSTRACT—*We used functional magnetic resonance imaging to assess whether self-construal priming can change adults' self-awareness induced during face perception. After reading essays containing independent or interdependent pronouns (e.g., I or we), participants were scanned while judging the head orientation of images showing their own and familiar faces. Neural activity in the right middle frontal cortex was greater when participants viewed their own rather than familiar faces, and this difference was larger after independent than after interdependent self-construal priming. The increased right frontal activity for participants' own faces relative to familiar faces was associated with faster responses. Our findings suggest that the neural correlates of self-awareness associated with recognition of one's own face can be modulated by self-construal priming in human adults.*

The ability to recognize one's mirror reflection indexes possession of cognitive processes underlying self-awareness (Gallup, 1970; Keenan, Gallup, & Galk, 2003) and has been observed in chimpanzees (Gallup, 1970) and infants (Amsterdam, 1972). Human adults respond faster to their own face than to familiar faces, particularly when responding with the left hand (Keenan et al., 1999). The latter result suggests right-hemisphere dominance in self-face recognition. Damage to or anesthetization of the right hemisphere results in difficulties in self-face recognition (Breen, Caine, & Coltheart, 2001; Keenan, Nelson, & Pascual-Leone, 2001). Brain-imaging studies have found increased right frontal activity associated with recognition of one's

own face (Platek, Keenan, Gallup, & Mohamed, 2004; Platek et al., 2006; Sugiura et al., 2000; Uddin, Kaplan, Molnar-Szakaca, Zaidel, & Iacoboni, 2005) and self-related encoding of personal traits (Craik et al., 1999), indicating that this brain area is engaged in operationalization of self-awareness that distinguishes the self from others.

Despite these findings, it remains unknown whether self-awareness can be changed in awake human adults. The study reported in this article provides novel evidence that self-awareness evoked by perceiving one's own face can be modulated by a priming task. We modulated self-awareness through a priming task that highlighted an independent or interdependent perspective on the self. An independent perspective depicts the self as an autonomous entity separate from others, whereas an interdependent perspective describes the self as a socially embedded entity with strong interconnectedness with others (Markus & Kitayama, 1991). Although self-construals are formed by the cultural environment, they can be shifted by the task of searching for independent or interdependent pronouns (e.g., *I* or *we*) in essays (Gardner, Gabriel, & Lee, 1999). To examine the interplay between self-construal priming and the neural substrates underlying self-awareness, we recruited participants to perform a face-identification task. Unlike previous brain-imaging studies that required subjects to explicitly identify their own and other faces (Platek et al., 2006; Uddin et al., 2005), our study required subjects to discriminate the head orientation of their own and familiar faces. We used this implicit face-recognition task because the explicit task may produce ceiling levels of self-awareness and thus block the influence of self-construal priming on self-awareness. If self-awareness induced during face perception can be augmented by shifting self-construal toward the independent perspective, frontal activity associated with self-face perception should be greater after independent than after interdependent self-construal priming.

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In a functional magnetic resonance imaging (fMRI) study, we tested this hypothesis in adults who were first primed with stories that differed with respect to whether they contained independent (e.g., *I, mine*) or interdependent (e.g., *we, ours*) pronouns. After the priming task, subjects were presented with images of their own face and the face of a familiar person and were asked to identify the head orientation of the faces (toward the left or right) while being scanned.

METHOD

Subjects

Twelve adults (6 males and 6 females; 20–42 years of age, mean = 24.3 ± 6.3) whose native language was Chinese participated in this study. All subjects were right-handed and had normal or corrected-to-normal vision. None had a history of neurological or psychiatric problems. Informed written consent was obtained from all subjects prior to scanning. This study was approved by a local ethics committee.

Stimuli and Procedure

For the self-construal priming, we used four stories written in Chinese. Two of the stories contained independent pronouns

(e.g., *I, mine*), and two contained interdependent pronouns (e.g., *we, ours*). Each two-paragraph story described a trip to the countryside. Each paragraph was accompanied by a question ("How many pronouns are there in this paragraph?") and two response options. Subjects were asked to read each paragraph, count the number of pronouns, and respond by pressing one of two buttons using the right index or middle finger. The content and order of the independent and interdependent self-construal stories were counterbalanced across subjects. In addition, subjects participated in a control condition in which they read two essays about the countryside that did not contain independent or interdependent pronouns. In this condition, subjects counted the number of nouns in the essays.

After reading each story in each condition, subjects performed a head-orientation task. They were presented with images of their own face, the face of a familiar person of the same gender, and a scrambled face bordered by a gray bar on the left or right side. Using a digital camera, we took 10 pictures of each subject's face and 10 pictures of the face of a person who worked in the same lab with the subject. The self and familiar faces, which portrayed neutral expressions, were oriented to the left (from 15° to 90°) in 5 images and to the right in the other 5 images (Fig. 1a). For each subject, we created a scrambled face
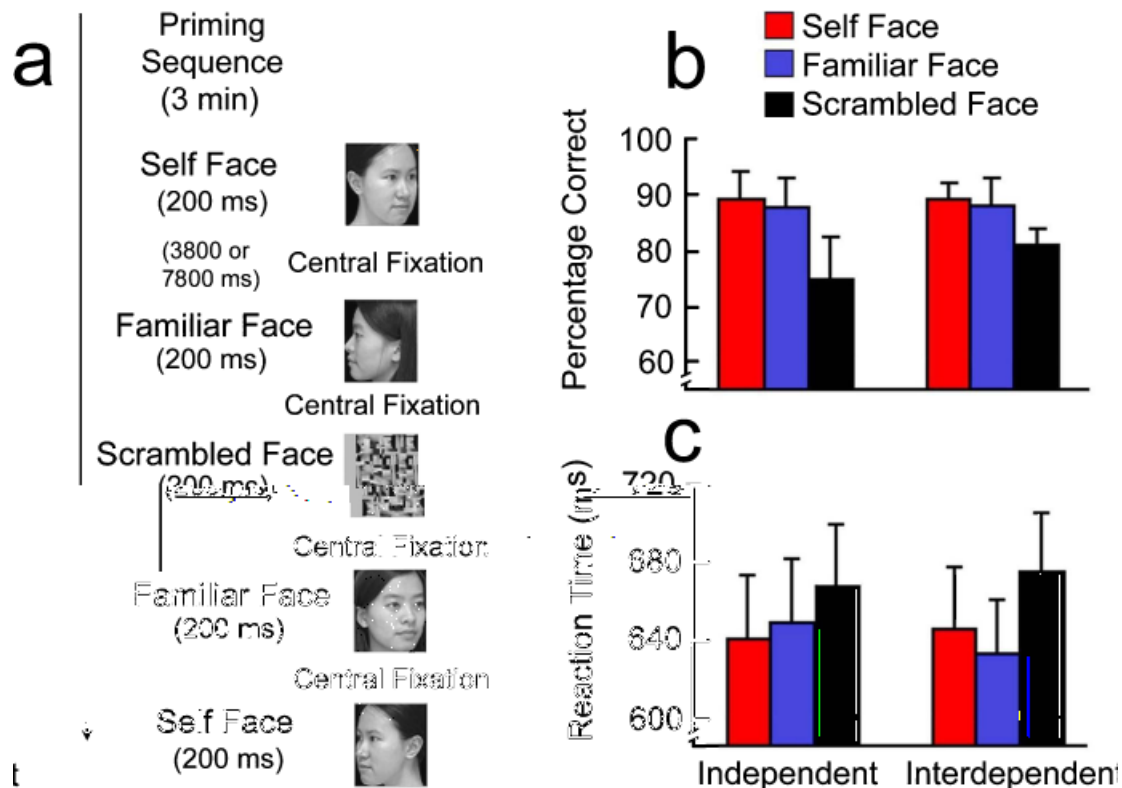
Fig. 1. The experimental procedure (a) and behavioral results (b, c). As shown in (a), after the self-construal priming task, subjects were scanned while being presented with their own face, a familiar face, and a scrambled face. They indicated the head orientation of the intact faces and the location of the gray bar next to the scrambled face by pressing a button with the right index or middle finger. The order of the independent and interdependent self-construal priming was counterbalanced across subjects. The graphs present (b) response accuracy and (c) reaction times for the three categories of faces, as a function of self-construal priming. Error bars represent standard deviations.

by cutting the images of the subject's face and the familiar face into 10×10 arrays and then reorganizing pieces selected from these two faces randomly into an image as large as a face stimulus. Each stimulus subtended a visual angle of $3.1° \times 2.9°$ at a viewing distance of 90 cm. Subjects indicated the head orientation of the intact faces and the location (left or right) of the gray bar in the scrambled faces by pressing a button using the right index or middle finger.

The stimuli were presented through an LCD projector onto a rear-projection screen located at the subject's head. After the priming task, which lasted for about 3 min, subjects were scanned during the head-orientation task. Six scans of 426 s were obtained from each participant. During each scan, the subject viewed 30 self-faces, 30 familiar faces, and 10 scrambled faces, which were presented in a random order. Each stimulus was presented for 200 ms, followed by a fixation period of 3,800 or 7,800 ms. We obtained two scans after the independent self-construal priming, two scans after the interdependent self-construal priming, and two scans after the control priming.

fMRI Image Acquisition and Analysis
Scanning was performed at Beijing MRI Center for Brain Research, on a 3-T Siemens Trio system using a standard head coil. Thirty-two transversal slices of functional images covering the whole brain were acquired using a gradient-echo echo-planar pulse sequence ($64 \times 64 \times 32$ matrix with spatial resolution of $3.4 \times 3.4 \times 4.4$ mm, repetition time = 2,000 ms, echo time = 30 ms, field of view = 220 mm, flip angle = 90°). Anatomical images were obtained using a standard 3-D T1-weighted sequence ($256 \times 256 \times 176$ matrix with spatial resolution of $0.938 \times 0.938 \times 1.3$ mm, repetition time = 1,600 ms, echo time = 3.93 ms).

SPM2 (Wellcome Department of Cognitive Neurology, London, United Kingdom) was used for fMRI data analysis. The functional images were realigned to the first scan to correct for head movement between scans. The anatomical image was co-registered with the mean functional image produced during the process of realignment. All images were normalized to a 2- $\times$ 2- $\times$ 2-mm^3 Montreal Neurological Institute template in Talairach space (Talairach & Tournoux, 1998) using bilinear interpolation. Functional images were spatially smoothed using a Gaussian filter with the full-width/half-maximum parameter set to 8 mm. The image data were modeled using a boxcar function. Contrasts were defined to compare activation between intact and scrambled faces and between self and familiar faces (in each priming condition). Statistical effects were first assessed in individual subjects using a fixed-effects analysis. Random-effects analyses were conducted across the group of subjects to allow population inferences. At the cluster level, significant activations were identified by p values smaller than .05 (corrected for multiple comparisons). Analyses of the interaction between face (self vs. familiar) and priming (independent vs. interdependent)

were conducted to assess the effect of self-construal priming on self-awareness. Region-of-interest (ROI) analyses were conducted to compare fMRI signal changes induced by the self and familiar faces in a cluster in the right fusiform gyrus identified by the contrast of intact versus scrambled faces and in a cluster of the right frontal cortex identified by the contrast of self versus familiar faces after independent self-construal priming. The parameter estimates of signal intensity associated with self relative to familiar faces in the right frontal cortex cluster were subjected to a repeated measures of analysis (ANOVA) with face (self vs. familiar) and priming (independent vs. interdependent) as factors.

RESULTS

Subjects were 100% correct in counting the number of pronouns in the self-construal priming task. Response accuracy in the head-orientation task was subjected to an ANOVA with factors of face (self, familiar, or scrambled) and priming (independent or interdependent). This analysis showed a significant main effect of face, $F(2, 22) = 16.28$, $p < .001$ (see Fig. 1b); response accuracy was lower for scrambled faces than for both self faces, $t(11) = 4.38$, $p < .001$, and familiar faces, $t(11) = 3.80$, $p < .005$, but response accuracy did not differ between self and familiar faces, $t(11) = 1.65$, $p = .128$. A parallel ANOVA of response time also showed a significant main effect of face, $F(2, 22) = 8.66$, $p < .002$ (see Fig. 1c); responses were slower for scrambled faces than for both self faces, $t(11) = 2.84$, $p < .05$, and familiar faces, $t(11) = 3.650$, $p < .005$. Response times tended to be shorter for self than for familiar faces after the independent self-construal priming, but this pattern was reversed after the interdependent self-construal priming, $F(1, 11) = 6.07$, $p < .03$.

The contrast of self versus familiar faces showed increased activation for the self faces in the right middle and inferior frontal cortex (centered at $x = 51$, $y = 38$, $z = 24$ and $x = 50$, $y = 33$, $z = 2$; $Z = 4.01$, $p < .01$; see Fig. 2a) after the independent self-construal priming. However, the same contrast failed to show any significant activation after the interdependent self-construal priming. A whole-brain interaction analysis was conducted to compare the difference between self and familiar faces in the two self-construal priming conditions. A significant interaction was identified in the right middle frontal gyrus ($x = 50$, $y = 38$, $z = 20$; $Z = 4.24$, $p < .05$); in this region, self-specific activity was larger after the independent than after the interdependent self-construal priming.

In an ROI analysis, we calculated parameter estimates of signal intensity in the right middle frontal cortex for self and familiar faces relative to scrambled faces. An ANOVA with priming (independent vs. interdependent) and face (self vs. familiar) as factors showed a reliable interaction, $F(1, 11) = 21.984$, $p < .001$. Post hoc analysis confirmed that signal intensity in the right frontal cortex was larger for self than for familiar faces after
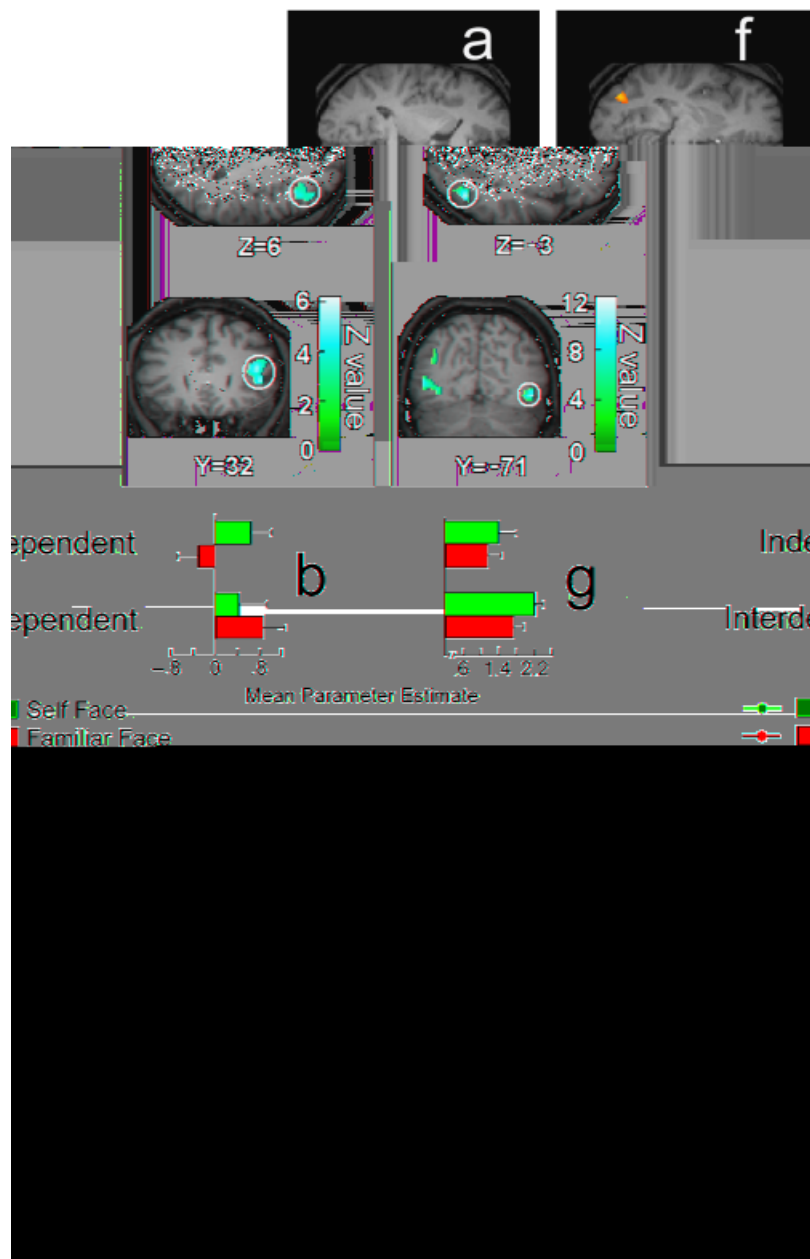
Fig. 2. Neural activations associated with identification of the self and familiar faces. The images at the top show brain areas with (a) stronger activation for self than for familiar faces after the independent self-construal priming (i.e., middle frontal cortex, highlighted by the circle) and (f) stronger activation for self and familiar faces than for scrambled faces (i.e., bilateral fusiform cortex; the circle marks the right fusiform gyrus). The graphs on the left show (b) parameter estimates of signal intensity in the right middle frontal cortex ($x = 50$, $y = 38$, $z = 20$) related to self and familiar faces (relative to scrambled faces) and the time courses of the blood-oxygenation-level-dependent (BOLD) signals in the right middle frontal cortex after the independent (c) and interdependent (d) self-construal priming and in the control condition (e). The graphs on the right show (g) parameter estimates of signal intensity in the right fusiform cortex ($x = 50$, $y = -72$, $z = -3$) related to self and familiar faces (relative to scrambled faces) and the time courses of the BOLD signals in the right fusiform cortex after the independent (h) and interdependent (i) self-construal priming and in the control condition (j).

the independent self-construal priming, $t(11) = 2.93$, $p < .014$ (Fig. 2b), whereas no significant difference was found between self and familiar faces after the interdependent self-construal priming, $F(1, 11) = 1.44$, $p = .178$. The time courses of the blood-oxygenation-level-dependent (BOLD) signals in the right middle frontal cortex after independent and interdependent

self-construal priming are shown in Figures 2c and 2d, respectively. The signal changes associated with self faces were larger than those linked to familiar faces only in the independent self-construal priming condition.

Relative to scrambled faces, self and familiar faces showed increased activation in the fusiform gyrus bilaterally ($x = 50$, $y = -72$, $z = -3$ and $x = -51$, $y = -70$, $z = 5$; Zs = 5.27 and 4.60, respectively, both ps $< .001$, corrected; see Fig. 2f). An ROI analysis of signal intensity in the right fusiform cortex failed to show any significant interaction between priming and face, $F(1, 11) = 1.504$, $p = .25$ (see Fig. 2g). In the right fusiform cortex, the time courses of the BOLD signals associated with the self and familiar faces were comparable in the two self-construal priming conditions (see Figs. 2h and 2i).

In the control condition, response accuracy and response time did not differ between self and familiar faces (both ps $> .05$), and the contrast between self and familiar faces did not show activation in any brain areas. Figures 2e and 2j show the time courses of the BOLD signals in the right middle frontal cortex and the right fusiform cortex in the control condition.

DISCUSSION

Previous neuropsychological studies showed that patients with brain damage to the right parietal or prefrontal cortex were unable to recognize themselves in a mirror even after coaching, a finding that suggests loss of self-recognition (Keenan, Wheeler, Gallup, & Pascual-Leone, 2000; Spangenberg, Wagner, & Bachman, 1998). Our fMRI results provide neuroimaging evidence for modulation of the neural correlates hl- avs revnltie a

mot,3 419(&(,3)17.C(B)10.h(s)0(u)26.n(g)0(,3-202.1(n)16.9(19)21.70())24.1(,3)23.5(c)0(l)24.the)v291.2(l)13.u(c)4(-)TJ0 -1.2576 TD5(1)25.i(-)f)·

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