

# Self-esteem modulates dorsal anterior cingulate cortical response in self-referential processing

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## ABSTRACT

Self-esteem can be defined as evaluations that individuals make about their worth as human beings. These evaluations are in part based on how we evaluate ourselves on our abilities, values, opinions, etc. compared with others or our past or ideal self; and they are also influenced by a thought that what others may think about us. Studies to date investigating the neural mechanisms underlying individual differences in self-esteem have focused mostly on the latter process (i.e. on how self-esteem is associated with neural correlates of processing feedback from others). However, given that people spend a lot of time thinking about themselves and evaluating their worth, we aimed to investigate neural mechanism underlying the association between levels of self-esteem and processing of self-relevant information. Seventeen participants completed a functional magnetic resonance imaging (fMRI) scan during which they were asked to evaluate whether a given statement is true about them (Self), an acquaintance of theirs (Other), or about general knowledge (Semantic). A whole brain correlational analysis revealed a significant negative correlation between levels of self-esteem and changes in activation of dorsal anterior cingulate gyrus (dACC, BA32) in response to evaluating self-relevant information (Self versus Other contrast). This result extends previous findings implicating this region in the association between processing evaluative feedback and levels of self-esteem and suggests that activity in this region is affected by self-esteem levels also when individuals are engaged in self-referencing and self-evaluation. Future studies should investigate whether these associations are affected differently based on valence of self-evaluations.

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## 1. Introduction

Self-esteem is a broadly defined personality variable referring to the degree to which an individual values and accepts him- or herself (Pruessner et al., 2005). It is one's value judgment of one's personal worthiness. This judgment expresses the degree of approval or disapproval of oneself (Crocker & Wolfe, 2001). It indicates the extent to which an individual believes him or herself capable, significant, and successful. Traditionally, *intrapersonal theories* have conceptualized self-esteem as a person's private self-evaluation (MacDonald, Saltzman, & Leary, 2003). *Interpersonal theories* on the other hand have been proposing that self-esteem reflects not only a person's beliefs about his or her personal characteristics but also the extent that the individual believes that other people regard those characteristics as important or valuable (MacDonald et al., 2003). Generally, *interpersonal theories* of self-esteem that tie self-esteem

to perceptions of one's acceptability to other people suggest that self-evaluations should predict global self-esteem to the degree to which an individual believes that a particular attribute is important for social acceptance (MacDonald et al., 2003).

To this end, researchers have explored whether brain regions responsive to rejection or acceptance are associated with self-esteem (Eisenberger, Inagaki, Muscatell, Byrne Haltom, & Leary, 2011; Onoda et al., 2010). Results demonstrated that participants who reported lower state self-esteem showed greater activity in regions involved in processing social rejection, including the bilateral anterior insula and the dorsal anterior cingulate cortex (dACC) (Eisenberger et al., 2011). The neural correlates of how trait self-esteem relates to neural responses to evaluative feedback have also been investigated and results showed that after social rejection, individuals with lower trait self-esteem reported increased social pain relative to individuals with higher trait self-esteem, and such individuals also demonstrated a greater degree of dACC activation during social rejection (Onoda et al., 2010).

Studies to date investigating the neural mechanisms underlying individual differences in self-esteem focused mostly on how self-esteem is associated with processing feedback from others

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(Eisenberger et al., 2011; Onoda et al., 2010). However, given that self-esteem refers to self-evaluation of self-worth, self-respect, or self-acceptance and people spend a lot of time thinking about themselves and evaluating their self-worth (Crocker & Wolfe, 2001; Rosenberg, 1965), we aimed to investigate neural mechanism underlying association between levels of self-esteem and processing of self-relevant information.

Given that: (1) previous research has shown that being socially excluded or rejected compared with being included or accepted leads to increased activity in the dACC (Eisenberger et al., 2011), and (2) low self-esteem is theorized to derive in part from repeated experiences of social rejection and criticism, with lower self-esteem levels being associated with greater activity in the dACC (Onoda et al., 2010), in the present study, we hypothesized that dACC would be more involved in those participants with low self-esteem as they are making self-appraisals. Furthermore, given that self-referential processing has been associated with activity in medial prefrontal cortex (mPFC) (Amodio & Frith, 2006), we hypothesized that levels of self-esteem would also be associated with changes in activity in mPFC.

## 2. Methods

### 2.1. Participants

Seventeen right-handed, healthy University students enrolled at Southwest University, China (9 male, aged 19–24 years; mean = 22.4 years, SD = 1.6) participated in the study. Participants did not have a history of psychiatric or neurological disorder, significant physical illness, head injury, or alcohol/drug abuse based on their self-report. After participants were given a complete explanation of the study, written informed consent was obtained from all of them. Participants were paid for their participation.

### 2.2. Materials

Participants completed the Rosenberg self-esteem scale (RSE), a questionnaire that assesses a person's overall evaluation of his or her self-worth (Rosenberg, 1965). The RSE is made up of 10 items such as 'On the whole, I am satisfied with myself' or 'I feel I do not have much to be proud of' and is coded on a 4-point scale ranging from 1 (strongly disagree) to 4 (strongly agree), with the negative items needing to be reverse scored.

### 2.3. Procedure

Upon arrival, the subjects completed the RSE. They then underwent a scanning session to complete the experimental task. In the functional MRI paradigm, subjects viewed three types of short sentences. They were asked to indicate whether the sentence was true about them, whether it was true about an acquaintance of theirs, or whether it was true about general knowledge. In the self-condition, the sentences were the items from the Coopersmith Self-Esteem Inventory (Coopersmith, 1967), such as "I can make up my mind without too much trouble" or "I often wish I were someone else". For each statement, the respondents choose "like me" or "unlike me" to indicate how they feel about themselves. The statements are phrased in both positive and negative directions. In the other condition, the sentences were same as in the self-condition except the subject was changed from "I" to "He". The respondents choose "like him" or "unlike him" to indicate how they feel about their brothers. In the semantic condition, sentences were about general knowledge and there were equal numbers of true/false items. The experiment comprised 144 trials, 48 per condition. The experimental design consisted of 12 blocks for each of the three conditions (Self, Other, and Semantic). There were three runs in the whole experiment and in each run, there were four blocks for each condition. In each 16 s block, four different sentences of the same type were presented for 4 s each, interleaved with the same duration rest periods consisting of a fixation cross presented in the middle of the screen. Order of presentation of the three conditions was randomized.

### 2.4. Imaging data acquisition

Images were acquired in a 3T Siemens TRIO MRI scanner. Functional data comprised 591 volumes acquired with T2\*-weighted gradient echo planar imaging (EPI) sequences. We obtained 32 echo planar images per volume sensitive to blood oxygenation level-dependent (BOLD) contrast (TR = 2000 ms; TE = 30 ms; 3 mm × 3 mm in-plane resolution; field of view [FOV] = 192). Slices were acquired in an interleaved order and oriented parallel to the AC–PC plane, with thickness of 3 mm, 0.99 mm gap. High-resolution T1-weighted 3D fast-field echo (FFE) sequences were obtained for anatomical reference (176 slices, TR = 1900 ms; TE = 2.52 ms; slice thickness = 1 mm; FOV = 250; voxel size = 1 mm × 1 mm × 1 mm).

### 2.5. Imaging data analyses

Data were analyzed using the Brain Voyager QX v2.3 software (Brain Innovation, The Netherlands). In order to see whether reaction times across conditions explain some variance in the data, we defined a block-wise parametric modulator based on standardized reaction time for each condition separately within each run (Buchs, Holmes, Rees, & Friston, 1998). After preprocessing, three contrasts were specified per single-participants analysis while controlling for the reaction times, Self versus Semantic; Other versus Semantic; and Self versus Other. The resultant single participant contrast images were then entered into second-level random effect-group analyses for each of the three corresponding contrast types. To identify whether the activations of the brain in three contrasts above were associated with the self-esteem scores of participants, the self-esteem scores derived from the RSE questionnaire were entered as a covariate in the correlation analysis assessing association between the betas and this external covariate. Inference of statistical significance of these three group analyses used uncorrected  $p$  value at least  $p < 0.001$ , in regions encompassing at least 10 voxels.

## 3. Results

### 3.1. Behavioral data

Repeated-measures ANOVA showed that there was a main effect of condition on the reaction times ( $F(2,32) = 7.817$ ;  $p < 0.01$ ), as response was slower for Semantic condition as compared to Self ( $p < 0.01$ ) and Other conditions ( $p < 0.05$ ). There was no significant difference in reaction times between Self and Other conditions.

We further assessed that in how many trials were the participants be able to complete within the allotted time for each trial (4 s). Results indicated that participants provided an answer within the time allotted for 95.8% of the trials in the Self condition, 95.3% of the trials in the Other condition, and 95.1% of the trials in the Semantic condition. Repeated-measures ANOVA showed that there was no main effect of condition.

The correlation between self-esteem score on RES scale outside of the scanner and total self-evaluation score in Coopersmith Self-Esteem Inventory in the scanner showed that these scores were significantly and positively correlated,  $r = 0.778$ ,  $p < 0.01$ .

### 3.2. Functional imaging results

The contrast of Self versus Semantic condition indicated that Self condition produced significant neural activation in ventral medial prefrontal cortex (BA9), superior frontal gyrus (BA8), posterior cingulate gyrus (BA31) and caudate nucleus (Table 1). In the contrast between Other versus Semantic condition, evaluation of close other produced significant neural activation in ventral medial prefrontal cortex (BA9), medial and superior frontal gyrus (BA8), middle and superior temporal gyrus (BA21 and BA39), and ventral posterior cingulate gyrus (BA23) (Table 1). Direct comparison between Self and Other conditions, which reflects evaluation and processing of self-relevant information, revealed a significant increase in neural activation in anterior cingulate gyrus (BA24) in the Self condition compared to the Other condition (Table 1).

To test whether brain regions previously shown to be sensitive to self-referential information demonstrated modulated activity based on self-esteem, whole brain correlations between self-esteem scores and the neural activation changes in the contrasts Self versus Semantic, Other versus Semantic, and Self versus Other conditions were conducted separately. The results showed only a significant negative correlation between self-esteem scores and the neural activation on the contrast of Self versus Other (Fig. 1), in right dorsal anterior cingulate gyrus (BA32).

## 4. Discussions

The major goal of the present research was to investigate the neural mechanism underlying association between levels

**Table 1**  
Coordinates of activation peaks.

| Region                    | L/R | Brodmann area | Talairach coordinates |     |     | t-Score | Cluster sizes |
|---------------------------|-----|---------------|-----------------------|-----|-----|---------|---------------|
|                           |     |               | X                     | Y   | Z   |         |               |
| Self–Semantic             |     |               |                       |     |     |         |               |
| Medial frontal gyrus      | L   | BA9           | −5                    | 45  | 20  | 10.77   | 16,752        |
| Superior frontal gyrus    | R   | BA8           | 16                    | 33  | 49  | 10.99   | 435           |
| Caudate                   | L   |               | −16                   | 10  | 13  | 7.71    | 329           |
| Posterior cingulate gyrus | L   | BA31          | −1                    | −53 | 23  | 8.69    | 13,994        |
| Other–Semantic            |     |               |                       |     |     |         |               |
| Superior frontal gyrus    | R   | BA8           | 16                    | 29  | 51  | 7.39    | 757           |
| Medial frontal gyrus      | R   | BA9           | −6                    | 50  | 17  | 6.94    | 10,832        |
| Superior temporal gyrus   | R   | BA39          | 48                    | −55 | 23  | 6.68    | 720           |
| Posterior cingulate gyrus | L   | BA23          | −1                    | −53 | 22  | 13.55   | 15,895        |
| Middle temporal gyrus     | R   | BA21          | 55                    | 4   | −17 | 5.11    | 404           |
|                           | L   | BA21          | −60                   | −6  | −10 | 4.41    | 411           |
| Self–Other                |     |               |                       |     |     |         |               |
| Anterior cingulate        | L   | BA24          | −1                    | 27  | 21  | 5.59    | 505           |

of self-esteem and processing of self-relevant information. We hypothesized that levels of self-esteem would be associated with dACC responses to self-referential processing, i.e. when participants are making self-appraisals to indicate how they feel about themselves compared to how they feel about close others. These findings support this hypothesis.

Previous studies designed to explore the brain correlates of participants' self-reflection have yielded a remarkably consistent body of results showing that cortical midline structures are implicated in self-referential thought and self-reflection (Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Northoff & Bermpohl, 2004). The medial prefrontal cortex (mPFC) and medial parietal/posterior cingulate (PCC) cortices have been shown to be engaged during tasks which require making specific judgments about one's own traits (D'Argembeau et al., 2005; Johnson et al., 2002; Ochsner et al., 2005; Van Overwalle, 2009). Our findings in the present study are consistent with this literature and show that Self compared to Semantic condition lead to significant neural activation in ventral medial prefrontal cortex, superior frontal gyrus, posterior cingulate gyrus and caudate nucleus.

Given that close others are often experienced as very similar to the self, it is possible that judgments of close others' characteristics may be processed by the same brain areas as judgments about the self (for review see Amodio & Frith, 2006). Previous results showed that the ventral part of the mPFC was also activated when people make trait inferences about familiar others, such as mother, relatives, and friends (Van Overwalle, 2009). In the present study, when participants evaluated how they feel about their brothers compared to Semantic condition, significant neural activation was observed in ventral medial prefrontal cortex, medial and superior frontal gyrus, middle and superior temporal gyrus, and ventral posterior

cingulate gyrus. Therefore, there was a degree of overlap with the brain regions involved in judgments about the self.

The key analysis of the present study assessed association between trait levels of self-esteem and self-referential processing. The findings revealed that activation in dACC in response to processing of self-referential items was negatively associated with trait levels of self-esteem. These results extend previous findings by Eisenberger et al. (2011) where changes in dACC in response to processing evaluative feedback was negatively associated with state levels of self-esteem. Together, these observations suggest that the mechanisms that tie levels of self-esteem with processing of self-referential material may be similar to the mechanisms that link state self-esteem with processing of evaluative feedback from other individuals. The similarity in neural underpinning between these two processes may explain how self-esteem can be shaped by both self-evaluations and evaluations given by others, as is suggested by interpersonal theories of self-esteem.

However, it is possible that these are not two separate processes, i.e. it may be possible that individuals with lower self-esteem may be more likely to think and evaluate themselves more negatively in the self-evaluation task, and that this may map onto dACC to the extent that this self-evaluation corresponds to believed negative social evaluations. In this case, for individuals with lower self-esteem, processing self-evaluations would involve dACC to the extent that these self-evaluations are triggering representation of negative social evaluations. In the present study, we cannot assess this distinction since we did not ask them how they think others would judge them on these statements. Therefore, future studies should assess this question further.

Furthermore, it is important to note that previous studies have investigated neural correlates of how state and trait self-esteem

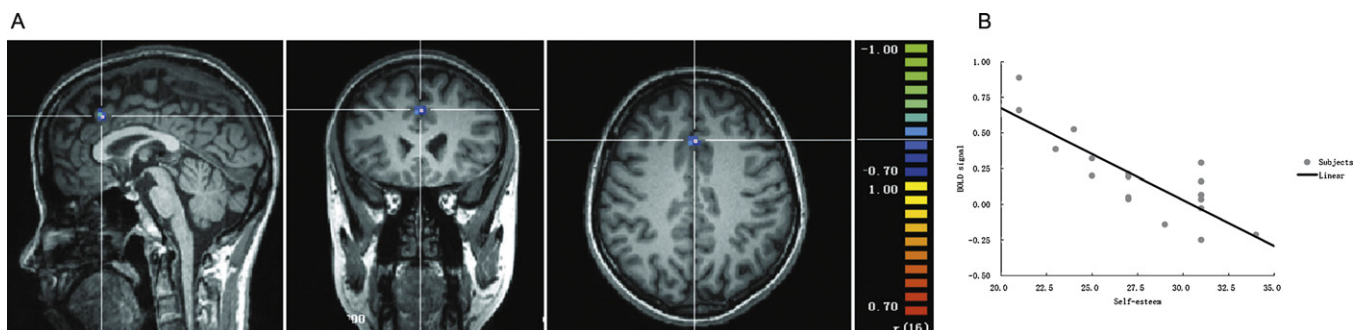


**Fig. 1.** (A) The correlation between the self-esteem scores and the neural activation in the contrast of Self versus Other condition (dACC: BA32,  $x=1$ ,  $y=24$ ,  $z=37$ ). (B) The curve estimation between the self-esteem scores and the BOLD signal of dACC (Self versus Other) in 17 subjects illustrates graphically the significant correlation observed in (A).

relate to specific type of evaluative feedback (positive versus negative) (Eisenberger et al., 2011; Somerville, Kelley, & Heatherton, 2010). The first study reported that individuals with low self-esteem showed enhanced activity to positive versus negative social feedback in the ventral anterior cingulate/medial prefrontal cortex (vACC/mPFC) (Somerville et al., 2010); while the second study revealed that in individuals whose session level self-esteem decreased following a feedback task (compared to those individuals whose self-esteem did not change or improved) showed significantly more mPFC activation in response to negative words (Eisenberger et al., 2011). Given that mPFC has been shown to process self-relevant information, it is somewhat surprising that we did not observe association between self-esteem levels and activity in this region in our study. However, in the present study we assessed association between self-esteem levels and overall self-referential processing rather than parceling out self-referential processing on positive versus negative sentences and this may account for the null result regarding mPFC. It would be important to investigate which neural mechanisms may underlie the association between self-esteem and the valence of self-referential information that is processed. However, the block design approach undertaken in the present study does not allow for this comparison and represents a limitation for answering that specific question. Event-related design would be recommended for future studies.

Another aspect of this study that requires additional mention is that it was conducted with college students in China. Self-esteem may affect cultural differences in self-evaluations. Researchers have provided evidence that cultural differences in self-evaluations are moderated by two factors: trait importance and self-esteem (Brown & Cai, 2010). In that study, culture and trait importance did not affect the self-evaluations of high self-esteem participants, but did affect the self-evaluations of low self-esteem participants. Whereas low self-esteem Americans evaluated their agentic qualities more positively than did low self-esteem Chinese, low self-esteem Chinese evaluated their communal qualities more positively than did low self-esteem Americans. Therefore, although the present study showed that Chinese individuals with lower self-esteem demonstrated a greater degree of dACC activation during Self- versus Other referential processing condition, it is possible that the neural mechanism underlying association between trait levels of self-esteem and processing of self-relevant information in Americans may show a different pattern.

Another limitation of the present study is that the participants were asked to choose a “brother” as an acquaintance in the Other condition. Thinking of a same-gender person (for male participants) can have different neural correlates than thinking of a person of the other gender (for female participants).

Overall, the results of the present study extend previous findings and provide additional support for interpersonal theories of

self-esteem by revealing that dACC, an area previously found to be involved in processing social evaluation and rejection, may be an important node that links levels of trait self-esteem also with processing of self-referential evaluations.

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