Neural correlates of evaluating self and close-other in physical, academic and prosocial domains

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ARTICLE INFO

ABSTRACT

Behavioral studies showed that self-concept can be distinguished into different domains, but few neuroimaging studies have investigated either domain-specific or valence-specific activity. Here, we investigated whether evaluating self- and mother-traits in three domains (physical, academic, prosocial) relies on similar or distinct brain regions. Additionally, we explored the topical discussion in the literature on whether vmPFC activity during self-evaluations is induced by valence or importance of traits. Participants evaluated themselves and their mothers on positive and negative traits in three domains. Across all domains, evaluating traits resulted in right dlPFC, left middle temporal cortex, bilateral thalamus, and right insula activity. For physical traits, we found specific neural activity in brain regions typically implicated in mentalizing (dmPFC, IPL). For academic traits, we found a brain region typically implicated in autobiographical memories (PCC), and for prosocial traits, social brain regions (temporal pole, TPJ) were activated. Importantly, these patterns were found for both self and mother evaluations. Regarding valence, rACC/vmPFC showed stronger activation for positive than for negative traits. Interestingly, activation in this region was stronger for highly important traits compared to low/neutral important traits. Thus, this study shows that distinct neural processes are activated for evaluating positive and negative traits in different domains.

1. Introduction

Understanding the way self-concept is built is important, as disturbances in self-image have been linked to disorders like depression, eating- and personality disorders (Orth, Robins, & Roberts, 2008; Stein & Corte, 2003; Vater, Schröder-Abé, Weisgerber, Roepke, & Schütz, 2015) and low performance at school or at work (Choi, 2005; Judge, Erez, & Bono, 1998). Self-concept has received much interest in recent brain imaging research, with the discovery that brain regions within the medial prefrontal cortex (mPFC) are specifically active when thinking about traits of self relative to traits of others (for meta-analyses, see Denny, Kober, Wager, & Ochsner, 2012; Murray, Schaer, & Debbané, 2012). These meta-analyses have highlighted that self-related regions are especially active when thinking of self relative to distant others, whereas less differentiation is observed when thinking about self-traits relative to traits of close others, possibly because close others are perceived as more similar to self. Indeed, several studies have reported that especially ventral mPFC (vmPFC) activity was increased for evaluations of self and similar others, but not for evaluations of dissimilar others (Heleven & Overwalle, 2016; Jenkins,

Macrae, & Mitchell, 2008; Mitchell, Macrae, & Banaji, 2006).

Compared to the number of studies that have examined general self-related areas, much less is known about the way self- and close-other evaluations are made for different domains. There is limited evidence for a difference in neural activity for physical versus character domains, such that evaluations about physical self-traits were associated with increased activity in lateral prefrontal cortex and posterior cingulate cortex (PCC), whereas character evaluations were related to activity in mPFC (Moran, Lee, & Gabrieli, 2010). Another study showed representations of social traits in the mPFC (Ma et al., 2014), whereas representations for competence traits were represented in mPFC and precuneus (Ma, Wang, Yang, Feng, & Overwalle, 2016). A prior study that focused on adolescent development showed stronger mPFC activity when evaluating one's own social traits from the perspective of friends, while mPFC activation was stronger for academic traits when making evaluations from the perspective of mothers (Pfeifer et al., 2009). However, this study did not directly test which neural regions differentiate between these domains for self-evaluations. In addition, the studies that distinguished between domains did not differentiate between positive and negative traits.

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One study that focused on valence differences suggested that vmPFC activity, particularly ventral anterior cingulate cortex (vACC), a region in vmPFC, is more active when the self-traits describe positive characteristics of self compared to when sentences describe negative traits (Moran, Macrae, Heatherton, Wyland, & Kelley, 2006). This is interesting because people tend to define positive traits as more important and negative traits as less important to self (Harter & Monsour, 1992). Indeed, a portion of the ventral mPFC was previously specifically activated in response to the attached importance to self-views (D'Argembeau et al., 2012). It has been suggested that vmPFC activity may relate to personal significance or importance of self-related contents rather than valence (D'Argembeau, 2013), but the exact function of the vmPFC remains largely unknown. Taken together, to date most neuroimaging studies on self- and close-other-evaluations focused on either domain-specific neural activity (Jankowski, Moore, Merchant, Kahn, & Pfeifer, 2014; Moran et al., 2010; Pfeifer et al., 2009) or on valence-related neural activity in vmPFC (Moran et al., 2006), but it is not yet known if these processes are carried out by overlapping or distinct brain regions.

To specify whether neural activities for evaluating traits in different domains and across valences are specific to self or are general for rating traits of people significant to the self, it is important to compare self-evaluations relative to evaluations of close others. Prior studies used several types of close others, such as friends (Benoit, Gilbert, Volle, & Burgess, 2010; Heatherton et al., 2006; Veroude, Jolles, Croiset, & Krabbendam, 2014) or family members (Ray et al., 2010; Zhu, Zhang, Fan, & Han, 2007). These studies show that there are brain regions that are specific for self, although others reported much overlap between self and close others (Krienen, Tu, & Buckner, 2010; Vanderwal, Hunyadi, Grupe, Connors, & Schultz, 2008). One interesting comparison condition is rating self versus mothers, as participants have usually known their mothers as long as they know themselves, although they can differ in closeness (Ray et al., 2010; Vanderwal et al., 2008; Zhu et al., 2007). Prior studies that have examined neural activity in relation to evaluating traits of self relative to traits of mothers reported predominantly similar activation patterns, but indicated stronger activation in mPFC and superior frontal sulcus in the self-versus mother contrast (Ray et al., 2010; Vanderwal et al., 2008; Zhu et al., 2007). Whether traits of different domains and valence are evaluated similarly or differently for close others has not yet been investigated.

The main goal of this study was to test whether trait evaluations in different domains and valences rely on overlapping or dissociable brain regions. Furthermore, we investigated whether the domain- and valence-related activation is different for self- compared to close-other-evaluations. Likewise, we tested whether similar or distinct brain regions are activated for general evaluation of self- and close-other traits. In addition, we explored the role of mPFC in valence and importance of traits. For this purpose, participants completed two trait evaluation tasks in which they rated themselves and their mothers on short trait sentences on a scale from 1 to 4 (Holt et al., 2011; Moran et al., 2010; Ray et al., 2010; Vanderwal et al., 2008; Zhu et al., 2007). The domains were based on prior studies showing a difference between physical and character traits (Moran et al., 2010) and within character traits between academic and prosocial traits (Pfeifer et al., 2009; Van Overwalle, Ma, & Baetens, 2016). All traits were presented in positive and negative valence sentences to examine to what extent valence based evaluations are dissociable from domain-specific evaluations.

First, we expected that evaluating physical traits would be associated with activity in lateral PFC whereas evaluating character (academic and prosocial) traits would result in activity in (ventral) mPFC (Ma et al., 2014, 2016; Moran et al., 2010). Prior studies have not yet dissociated between academic and prosocial domains, but it would be expected that evaluations in the academic domain rely more on autobiographical memory processes such as the posterior cingulate cortex (Fink et al., 1996; Summerfield, Hassabis, & Maguire, 2009), while evaluations in the prosocial domain would be expected to rely more on

social brain regions including anterior temporal lobe, superior temporal sulcus (STS) and temporal parietal junction (TPJ) (Frith, 2007; Ross & Olson, 2010). For the valence comparison we expected that vmPFC would be more involved for evaluating traits of positive valence over negative valence (Moran et al., 2006). Second, we expected largely overlapping activations for evaluating self- and mother-traits across all domains and valences (Ray et al., 2010; Vanderwal et al., 2008; Zhu et al., 2007). Third, as an earlier study suggested that the stronger vmPFC activity for positive than for negative trait evaluations may result from a greater assigned importance to positive than to negative traits (D'Argembeau, 2013), we explored the potential role of importance in vmPFC activation.

In summary, in this study participants evaluated positive and negative trait sentences in the physical, academic and prosocial domain for both self and mother. We aimed to examine the differential brain regions involved in making evaluations in different domains and valences regarding self and mother. Moreover, we explored contributions of importance in valence-specific activation (D'Argembeau, 2013; Moran et al., 2010) in evaluations of self and mother.

2. Method

2.1. Participants

Participants were 31 right-handed adults, one of whom one was excluded due to excessive head movements during the fMRI scan (more than 3 mm). The resulting sample consisted of 30 healthy adults (15 female) between 20 and 24 years old (mean age = 22.6 years, $SD = 1.2$ years). IQ was estimated using four subtests of the WAIS-III (Picture Completion, Similarities, Block Design and Arithmetic). Estimated IQ scores fell within the normal range: all IQ scores fell between 87.5 and 126.25 ($M = 107.17$, $SD = 8.86$). All participants signed informed consent before inclusion in the study and the study was approved by the University Medical Ethical Committee. Prior to the scan session, participants were screened for MRI contra indications and self-reported psychiatric diagnoses or psychotropic medication.

2.2. Task description

The fMRI task (see Fig. 1) consisted of two runs of 60 trials, each lasting approximately 6 min. In both runs, participants were presented with 60 sentences describing either positively or negatively valenced traits. These traits belonged to either the physical domain (e.g. 'I am unattractive), to the academic domain (e.g. 'I am smart'), or to the prosocial domain ('I help others'). Twenty sentences were shown for each domain; ten with a positive valence and ten with a negative valence.

In the first part, the 'Self' task, participants had to indicate to what extent the trait sentences applied to them. They responded by pressing a button between 1 ('not at all') and 4 ('completely') with their right hand. In the second part, the 'Mother' task, participants responded to the exact same sentences but this time indicated to what extent the traits applied to their mother. Before the MRI session, participants practiced 3 items per domain for both the Self and Mother experiment. During practice, different trait sentences were shown than during the actual experiment.

Each trial began with a 400 ms fixation cross. Subsequently, the stimulus was presented for 5000 ms, which consisted of the trait sentence and the response options (1–4). Within this timeframe, participants could rate themselves or their mother on the trait sentence. To assure participants that their choice had been registered, the number they chose turned yellow for the remaining stimulus time. If the participant failed to respond within the 5000 ms, they were shown the phrase 'Too late!' for 1000 ms. These trials were modelled separately and were not included in the analysis. Too late responses occurred on 0.2% of the trials in the Self task and on 0.7% of trials in the Mother