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Differential neural activity and connectivity for processing one's own face: A preliminary report

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ABSTRACT

The experience of self is unique and pivotal to clinically relevant cognitive and emotional functions. However, well-controlled data on specialized brain regions and functional networks underlying the experience of self remain limited. This functional magnetic resonance imaging study investigated neural activity and connectivity specific to processing one's own face in healthy women by examining neural responses to the pictures of the subjects' own faces in contrast to faces of their own mothers, female friends and strangers during passive viewing, emotional and self-relevance evaluations. The processing of one's own face in comparison to processing of familiar faces revealed significant activity in right anterior insula (AI) and left inferior parietal lobule (IPL), and less activity in right posterior cingulate/precuneus (PCC/PCu) across all tasks. Further, the seed-based correlation analysis of right AI, and left IPL, showed differential functional networks in self and familiar faces contrasts. There were no differences in valence and saliency ratings between self and familiar others. Our preliminary results suggest that the self-experience cued by self-face is processed predominantly by brain regions and related networks that link interoceptive feelings and sense of body ownership to self-awareness and less by regions of higher order functioning such as autobiographical memories.

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1. Introduction

The neural processing of self is regarded as special and distinct from the processing of others, as the experience of self is unique and cannot be completely shared with others. The ability to appreciate the uniqueness and distinctiveness of self from others plays a pivotal role in social relationships, interactions and emotional regulation. Recently, there has been increased interest in understanding the neural basis of self-representation as several neuropsychiatric conditions are associated with disturbances in the subjective experience of self. For example, increased negative self-attribution or self-focus may be related to the development of depression (Grimm et al., 2009), and deficiency in self-monitoring agency and saliency processing may contribute to hallucinations, delusions and the passivity phenomenon in schizophrenia (Spence et al., 1997; Kircher and Leube, 2003). Hence, elucidating the neural correlates of self-processing may have significant clinical implications as these could be used as potential brain markers of self-disturbance in the etiology and treatment outcomes of major psychiatric disorders.

Considerable progress has been made over the last decade in our understanding of the neural mechanisms of self-referential processing in the facial domain. The ability to recognize oneself by recognizing one's own face (mirror self-recognition) has been linked to the capacity for introspection about oneself (self-awareness) and the mental state of others (Theory of Mind) (Gallup, 1970, 1982). Gallup proposed this model based on the observation that chimpanzees and orangutans that live in complex social groups are capable of recognizing themselves in the mirror. However, some view that in non-human animals, mirror self-recognition requires only kinesthetic self-knowledge and does not involve access to other mental states or self-awareness (Mitchell, 1997; Morin, 2006). In previous brain-imaging studies involving human participants, the recognition of one's own face was from pictures and therefore did not require kinesthetic information (Devue and Bredart, 2011). Bruce and Young (1986) proposed a neural model of face recognition that was recently modified by Gobbini and Haxby (2007). According to this revised model, recognizing personally familiar faces including one's own face

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entails recognition of visual appearance, spontaneous retrieval of biographical information and activation of appropriate emotional response. Based on this model, visual presentation of one's own face is expected to recruit areas associated with self-awareness, knowledge and subjective feelings or emotions. The neural systems for personally familiar face processing or processing of one's own face include visual perceptual brain areas (inferior occipital, fusiform gyri), areas engaged in processing emotional responses (amygdala, insula, caudate) and person knowledge/autobiography (precuneus, posterior cingulate cortex, anterior cingulate cortex, superior temporal cortex, temporo-parietal junction, and anterior temporal area). Based on this neural model of face recognition, it is possible that the neural basis of self-specific processing can be examined in visual perceptual, emotional and cognitive domains by comparing one's own face as a self-specific stimulus with non-self faces.

Using designs in which the subject's own face is contrasted with familiar and unfamiliar faces, several functional imaging studies have examined whether mental or neural representations of self are distinct from representations of others (Kircher et al., 2000; Sugiura et al., 2000; Kircher et al., 2001; Platek et al., 2004; Sugiura et al., 2005; Uddin et al., 2005; Platek et al., 2006; Sugiura et al., 2006; Devue et al., 2007; Platek and Kemp, 2009; Taylor et al., 2009). A meta-analysis of functional magnetic resonance imaging (fMRI) studies of self-face recognition found significant activation in 26 brain regions, including lateral and medial prefrontal, parietal, temporal, occipital areas, anterior and posterior cingulate regions, and subcortical and limbic structures (Platek et al., 2008). Among these brain structures, four areas (left fusiform gyrus, bilateral middle and inferior frontal gyrus, and right precuneus (PCu)) were consistently activated in five or more studies. In a recent meta-analysis, additional brain regions such as the anterior cingulate cortex, insula, fusiform gyrus, and inferior parietal lobule were also reported to be consistently activated in self-recognition in the facial domain (Devue and Bredart, 2011). The specific involvement of perigenual anterior cingulate and insula has been shown in self-specific processing in a descriptive meta-analysis of all studies with with self–aces and other self specific stimuli (Northoff et al., 2011).

There are some methodological limitations in previous imaging studies that need to be addressed. Most previous studies examining self-specific processing have not controlled adequately for general evaluation functions including self-relatedness and affective responses related to personal familiarity (Gillihan and Farah, 2005; Legrand and Ruby, 2009). Hence, the results of previous imaging studies may be confounded by evaluative functions or judgments related to personal familiarity. For example, the cortical midline structures (medial prefrontal cortex, anterior cingulate cortex, precuneus, and posterior cingulate) associated with self-specific stimuli have also been implicated in processing of non-self personally familiar stimuli (Gillihan and Farah, 2005; Northoff et al., 2011). Another methodological issue is that studies using information-processing paradigms with high cognitive load in face-recognition tasks rely predominantly on cognitive or attentional systems (Sugiura et al., 2000, 2005, 2006), and the results of these studies may correspond predominantly to cognitive accounts of self. According to the emerging concept of self in cognitive neuroscience, the unique features of self-specific processing may be related to the subjective experience of self in the experiential domain (Northoff et al., 2006), which is primarily anchored in sensorimotor and homeostatic processing involving interoceptive and exteroceptive functions (Legrand and Ruby, 2009). Hence, to study the neural mechanisms related to self-specific processing in the facial domain, it is critical to use a paradigm that controls for the effects of personal familiarity and evaluative functions on self-relatedness and emotional responses through tasks with low cognitive demand and where face recognition is not explicitly under investigation.

Although previous studies have examined specialized brain regions of self-specific processing, our understanding of functional networks of these regions remains limited. Mapping the functional connectivity of brain regions responsive to one's own face is crucial to study the spatially distributed, domain-specific network of areas that underlie cognitive, emotional and perceptual processing of self. The concurrent activations of multiple brain regions observed during self-related tasks in subtraction paradigms shown in previous studies may not represent a single unified network and could reflect distinct networks (Seeley et al., 2007).

The objective of this study was to examine the distinct neural representations of self and their functional networks in healthy women using one's own face and non-self face conditions (mother, female friend and two female strangers), controlling for the degree of familiarity and for emotional and personal relevance in a paradigm in which self-face recognition was not explicitly under investigation.

2. Methods

Ten healthy, right-handed, female volunteers participated in this study. The participants were between the ages of 20 and 30 years (mean = 25.0, S.D. = 3.4) and had a mean education level of 18 years. To minimize gender variation, only female subjects and gender-matched personally familiar (mother and female friend) and non-familiar controls (older and younger female strangers) were included. The mother and a close non-sexual female friend were chosen as personally familiar others to control for familiarity, person knowledge, emotional responses and self-relatedness.

The Rosenberg self-esteem scale was used to confirm that subjects had self-esteem within the normal range of 15–30 (Rosenberg, 1965) as we predicted that low self-esteem may have an effect on self referential processing. All participants had self-reported stable relationships with their biological mothers since childhood. Furthermore, they received adequate maternal care before the age of 16 years, as determined by the Parental Bonding Instrument (PBI), a retrospective self-report measure of perceived parental bonding before the age of 16 years (Parker et al., 1979). Subjects with a score of 23 and above on the mother care subscale of the PBI were included in the study (Pruessner et al., 2004).

Subjects with a history of early abuse or current conflict in the maternal relationship were excluded. The participants were asked to select the close friend based on length of acquaintance of more than 1 year, frequent interaction (at least once a month), and shared values and activities.

The participants were screened for a history of current or previous serious medical and neurological disorders by self-report and physician-directed medical review of systems. The Structured Clinical Interview for DSM-IV (SCID) (First et al., 1997) was used to rule out current and previous psychiatric illnesses and substance abuse; no subjects had an Axis I diagnosis. Current anxiety and depressive symptoms were measured using Beck's Anxiety Inventory (BAI) and Beck's Depression Inventory (BDI) (Beck et al., 1979, 1988) as anxiety and depressive symptoms may influence neural processing of emotionally relevant stimuli. Right handedness was determined by the Edinburgh Handedness Inventory (Oldfield, 1971). Subjects who were pregnant or had other medical contraindications for magnetic resonance imaging (MRI) were excluded. This study was approved by the institutional review board of Emory University, Atlanta, Georgia, and USA. All participants gave written informed consent before their participation and were compensated 75 USD for their time.

2.1. Stimuli and tasks

The stimulus set for each subject consisted of six pictures. Each subject was asked to provide a full-face digital color head and shoulders photograph of her own face (self), the face of her mother, and the face of a close female friend (age similar to subject), all with a smiling expression and eyes looking forward, and all taken within the past year.

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