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The neural correlates of direct and reflected self-knowledge

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Socrates said that in order to lead a balanced life one must, "know thyself." In two fMRI experiments, the present study examined the mechanisms mediating two ways in which the self can be known: through direct appraisals (i.e., an individual's own self-beliefs) and reflected appraisals (i.e., an individual's perception of how others view him or her). Experiment 1 examined the common and distinct neural bases of direct appraisals of the self, close others, and normative judgments of trait desirability. All three judgment types activated medial prefrontal cortex (MPFC) to a similar degree. Experiment 2 examined the common and distinct neural bases of (1) direct appraisals of self, a close other or a non-close other, and (2) reflected appraisals made from the perspective of a close or a non-close other. Consistent with Experiment 1, all judgment types activated MPFC. Direct appraisals of the self as compared to others more strongly recruited MPFC and right rostrolateral PFC. Direct appraisals as compared to reflected appraisals recruited regions associated with a first-person perspective (posterior cingulate), whereas reflected as compared to direct appraisals recruited regions associated with emotion and memory (insula, orbitofrontal, and temporal cortex). These results support models suggesting that MPFC mediates meta-cognitive processes that may be recruited for direct and reflected self appraisals depending upon the demands of a specific task.

Keywords: Medial prefrontal cortex; Self; Self-reference; Person; Perception theory of mind

Introduction

How do we know what we are like? Am I friendly? Am I outgoing? Am I aggressive or anxious or eager? To answer these questions, contemporary social psychological theories suggest that there are at least two appraisals of the self upon which we draw (Baumeister, 1998; Fiske, 2004; Kenny and DePaulo, 1993; Shrauger and Schoeneman, 1999). Direct appraisals draw primarily upon semantic self-knowledge abstracted from previous experiences, although in some cases, self appraisals might draw upon episodic knowledge of specific life events (Kihlstrom et al., 2003; Klein et al., 1989, 1996; Markus, 1977; Tulving et al., 1988). By contrast, reflected appraisals draw on our beliefs about how we are seen by others. The person 'seen' in reflected appraisals has been termed "The Looking Glass Self" (Cooley, 1902; Mead, 1934).[1]

For much of the past century, behavioral researchers have asked two distinct but related questions about the mechanisms underlying direct and reflected appraisals. The first question is whether direct appraisals of the self are 'special,' insofar as they draw upon different informational bases and inferential processes used to directly appraise other individuals. For example, it is possible that evaluating your own friendliness recruits highly accessible memory representations that are more structured and complex than those used to evaluate the friendliness of a work colleague (Dweck et al., 2003; Higgins and Bargh, 1987; Symons and Johnson, 1997). At best, there is mixed evidence to support this claim. On one hand, memory is enhanced for traits evaluated in relation to the self in comparison to other targets. This memory advantage has been argued to reflect something 'special' about the unique organizational structure of self-knowledge (Maki and McCaul, 1985; McCaul and Maki, 1984; Rogers et al., 1977). On the other hand, similar levels of memory are observed for stimuli whose representations are equated for complexity of organization and/or elaboration (Klein and Kihlstrom, 1986; Symons and Johnson, 1997).

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[1] A variant on this second possibility is that self-knowledge derives not just partially, but almost completely from our perceptions of others (Cooley, 1902; Lewin, 1951; Mead, 1934; cf. Bem, 1967).

The second question is to what extent direct and reflected appraisals – which are often conceptualized as distinct processes – may share similar inferential and informational bases. For example, our beliefs about what others think of us could be based on our own beliefs about ourselves. Research suggests that this may be the case: reflected appraisals are correlated more strongly with direct self appraisals than they are with actual feedback from others (Kenny and DePaulo, 1993; Krueger, 2003). This suggests that reflected appraisals may reflect our own beliefs about ourselves more than they reflect accurate knowledge about others' views.

Although no prior functional neuroimaging work has included both direct and reflected appraisals, the results of studies examining each in isolation can be used to formulate predictions about the common and distinct neural correlates of the two types of self appraisals. To examine direct self appraisals, some studies have adapted methodological techniques from studies of the self-reference effect in memory. This approach contrasts self-descriptive judgments with other types of judgment to isolate neural systems associated specifically with the access of information about the self. As illustrated in Table 1, comparison conditions have included judging traits of familiar persons (i.e., a political figure, a close other), judging the social desirability of traits, and whether the words possess some perceptual characteristic unrelated to their meaning. Results have suggested that self-reference may be both 'special' and ordinary: greater MPFC activation is found when judging whether trait words describe the self as compared to a non-close other (George Bush), but both types of judgments recruit other regions involved in memory retrieval, such as left inferior prefrontal cortex (PFC), to the same degree as the other-referential judgments (Kelley et al., 2002; Macrae et al., 2004). MPFC

Table 1
Judgment conditions included in studies of self-reference and perspective taking

Target of belief	Perspective							
	Direct appraisals		Reflected appraisals				Normative appraisals	
	Self (what you think)		Close other (what a friend would think)		Non-close other (what a non-close other would think)		Generic other (what the average person would think)	
Self	Craik Kelley Kircher[1] Lieberman Fossati Schmitz Ochsner Ruby '03[3] Ruby '04[4] Vogeley[5]	Experiment 1 *Self* Experiment 2 *You* *About* *Self*		Experiment 2 *Friend* *About* *You*		Experiment 2 *Other* *About* *You*	None	
Close other/ friend	Schmitz	Experiment 1 *Other* Experiment 2 *You* *About* *Friend*	Ruby '04[4]		None		None	
Non-close other	Craik Kelley	Experiment 2 *You* *About* *Other*	None		Ochsner[2] Vogeley[5]		None	
Desirability or positivity of trait	None		None		None		Fossati[6] Ruby '03[3] Schmitz[7]	Experiment 1[7] *Positive*
Perceptual characteristic of stimulus	Craik Fossati Kelley McRae	Experiment 1 *Syllable* Experiment 2 *Curved* *Lines*	None		None		None	

Notes. For each cell, left hand column list studies examining different types of direct and/or reflected appraisals, whereas the right hand column indicates which types of appraisals were included in the present experiments. Text in italics indicates the instructions given in the present experiments for specific types of direct and reflected appraisals. *Targets* are the individuals about whom thoughts/beliefs/feelings are held and judgments are made. *Perspectives* refer to the person who holds the thought/belief/feeling. Among studies examining judgments about what would be believed by another person (i.e., what is 'seen' or 'believed' from their perspective), only the present Experiments 1 and 2 involve reflected appraisals of the beliefs that another person holds about you, the experimental participant (see text for full description of conditions in present experiments). In this context, a normative perspective is a form of reflected appraisal that involves neither a specific 'reflector' of beliefs nor a specific target of them. *Superscripted numerals* indicate: [1]Judging whether a trait adjective describes you (yes/no); [2]judging your own emotional response to a photo or the emotion expressed by a figure in the photo; [3]judging what you believe or the average person would believe about medical/health issues; [4]predicting either your own or your mother's emotional reactions to an event; [5]judging what you believe or a vignette character believes about an event described in the vignette; [6]judging social desirability of trait; [7]judging positivity of trait. Judgments 3, 6, and 7 involve perspective taking to the extent that participants make their judgments based on they perceive an average person would believe.

activation has been reported during similar kinds of self-referential assessment (Craik et al., 1999; Fossati et al., 2003; Johnson et al., 2002) as well as during other types of self-reflective processing that involve awareness of one's own current thoughts or feelings (e.g., Gusnard and Raichle, 2001; Lieberman et al., 2004; McGuire et al., 1996; Ochsner et al., 2004).

On the basis of these findings, it has been suggested that MPFC may play a special role in mediating access to self-knowledge in general (Gusnard and Raichle, 2001; Kelley et al., 2002; Macrae et al., 2004). Other findings suggest, however, that self-reference may involve other regions as well. For example, self-referential processing has been associated with activity in posterior cingulate/precuneus (Fossati et al., 2003; Johnson et al., 2002; Kircher et al., 2002; Schmitz et al., 2004) and is disrupted by transcranial magnetic stimulation over this region (Lou et al., 2004). Furthermore, some studies have failed to show greater MPFC activation, observing instead activation in lateral prefrontal or parietal systems (Kircher et al., 2002; Schmitz et al., 2004).

Two studies of self-reference included normative appraisals of trait desirability. The first observed greater MPFC activity for self appraisals compared to appraisals of the positivity of trait adjectives (Schmitz et al., 2004), and the second found similar patterns of MPFC activity for self appraisals and appraisals of trait desirability (Fossati et al., 2003). Four other studies have directly compared first-person (what I think/feel) as compared to third-person (what another person thinks/feels) judgments about beliefs and feelings that are not directly related to the self. Three of these studies suggest that greater MPFC activation is associated with judging another's beliefs or emotions as compared to judging either one's own belief or emotions (Ruby and Decety, 2003, 2004; Vogeley et al., 2001) or non-mentalistic baseline judgments (Ochsner et al., 2004). One study found greater MPFC activation for self than for other judgments, however, and that other judgments activated left lateral PFC (Ochsner et al., 2004). More generally, studies comparing mental and non-mental state inferences about others have found MPFC activation along with other regions including the superior temporal sulcus, posterior cingulate/precuneus, and temporal pole (for review, see (Adolphs, 2003; Gallagher and Frith, 2003; Ochsner et al., 2004).

The preceding review presents a complex and somewhat contradictory picture of the relationship between specific brain systems and direct or reflected appraisals of the self. On one hand, it is possible that there are consistent neural correlates of each type of appraisal, but the ability to detect them may have been obscured by methodological shortcomings. For example, in prior work, the degree of relationship intimacy or familiarity has not been systematically manipulated, which could influence recruitment of brain systems. On the other hand, extant results do suggest that MPFC, as well as a number of other commonly activated posterior medial and temporal regions, plays a role in drawing inferences about enduring traits and mental states. Therefore, they may play important roles in both direct and reflected appraisals about the self concept.

The specific question addressed by the present research is: what exactly are those roles? Complexities and inconsistencies aside, prior research suggests three possibilities. The first is that MPFC (or some subregions of it, as well as allied medial and temporal regions) supports inferences about one's own current states and dispositions, perhaps because MPFC supports access to internal cues available only for one's own mental states (Gusnard et al., 2001; Kelley et al., 2002; Ochsner et al., 2004). The second is that MPFC is involved specifically in adopting the perspective of and/or making judgments about the mental states of other people (Ruby and Decety, 2003, 2004). The third possibility is that MPFC performs computations common to both of these processes, including those involved in meta-cognitive judgments that require explicit representation of what one knows (Gallagher and Frith, 2003; Lieberman and Pfeifer, in press; Ochsner et al., 2004). In this case, activation in MPFC (and allied regions) may depend upon the meta-cognitive processing demands intrinsic to a specific experimental situation.

The present studies address these possibilities using functional magnetic resonance imaging in two experiments that systematically varied the target of judgments about personality (thereby varying the kind of personal knowledge accessed) as well as the first or third-person perspective taken when making those judgments (thereby varying direct versus reflected appraisals). A particular strength of this study was the opportunity to compare results from two experiments that included both overlapping and distinct task conditions and statistical analyses but used slightly different experimental methods and data collected from different scanners. Comparing and contrasting patterns of activation across two experiments that systematically varied task conditions should provide converging evidence concerning the common and distinct processes underlying the direct and reflected routes to self-knowledge.

Experiment 1

Experiment 1 addresses two specific questions concerning the neural systems specifically recruited during direct appraisals of one's own self concept. First, we asked whether judging one's own personality traits is similar to judging the traits of a close other with whom one has a great deal of information/experience. Second, we asked whether making self-assessments of personality is similar to making assessments of social desirability. The latter comparison included a condition that required adopting the normative perspective of the "average person" and provided a control condition for the possibility that self appraisals reflect processes that bias us to think positively of ourselves (Robins and Beer, 2001; Taylor and Brown, 1988).

Methods

Participants

17 Participants (9 female, *M* age = 29 years) were recruited in compliance with the human subjects regulations of the University of California, Berkeley, and were compensated $15/h for their participation. All participants were screened for medications or psychological and/or neurological conditions that might influence the measurement of cerebral blood flow.

Behavioral paradigm

Participants completed four types of blocks (see Table 1) each comprised of 6 positive and 6 negative trait adjectives drawn from the normed lists of Craik et al. (1999). Word length, number of syllables, valence, and frequency ratings for word types were equated across four stimulus sets that were counterbalanced across four judgment types. On Self blocks, participants were instructed to judge whether the adjective described them. On Other blocks, participants judged whether the adjective described a close other that had been identified by each participant before the experiment began. On Positive blocks, participants judged whether each adjective described a trait that most people would consider a positive personality characteristic. On Syllable blocks, participants judged whether the adjective contained two syllables. Each of the 12 trials in each block began with a screen containing an instructional cue above a fixation point for 2.2 s (all timing was TRs). The instructional cue remained but the crosshair was then replaced with a trait adjective for 2.2 s, while participants made a yes/no binary judgment. Participants made their judgments using the thumbs of their left and right hands on a two-button response box. Positive and negative words were presented in an optimized pseudorandom order within blocks with jittered intertrial intervals (ITIs) that varied from 4 to 8 s with an average interval of 5.16 s (Donaldson et al., 2001). The task comprised four 8-min 56-s scans each consisting of 4 pseudorandomly ordered blocks (each lasting 110 s, including 12 4-s trials per block and jittered ITIs) with 24-s fixation rest periods following each block.

Stimuli were projected onto a screen mounted on a custom head coil that limited head motion using foam padding. Stimulus presentation and response collection were controlled by the program E-prime running on a Windows 98 Computer.

MRI data acquisition

All images were acquired with a 4-T Varian INOVA MR scanner and a TEM send and receive RF head coil. Functional images were acquired during four runs lasting 536 s each, using a two-shot gradient echo echo-planar image (EPI) sequence with a repetition time (TR) of 2.2 s (echo time of 28 ms, and flip angle of 20°), resulting in 244 total volumes acquired. Whole brain volumes consisted of twenty 3.5-mm axial slices with a 5-mm interslice gap. Each slice was acquired with a 22.4 cm^2 field of view with a 64 × 64 matrix size, resulting in an in-plane resolution of 3 × 3 mm. High-resolution (0.875 × 0.875 mm) in-plane T1-weighted anatomical images were also acquired using a gradient echo multislice (GEMS) sequence for anatomical localization. Finally, MP-Flash 3D T1-weighted scans were acquired so that functional data could be normalized to the Montreal Neurological Institute (MNI) atlas space.

MRI data analysis

All statistical analyses were conducted using SPM2 (Wellcome Department of Cognitive Neurology). Functional images acquired from the scanner were reconstructed from *k* space using a linear time interpolation algorithm to double the effective sampling rate. Image volumes were corrected for slice-timing skew using temporal sinc interpolation and corrected for movement using rigid-body transformation parameters. Images were then smoothed with an 8-mm FWHM Gaussian kernel and masked using a full-brain mask to remove extraneous signal as a result of ghosting. To remove drifts within sessions, a high-pass filter with a cutoff period of 200 s was applied.

A fixed effects analysis was used to model both block and event-related responses for each participant. Responses related to the instructional cues and the onset of each positive or negative word stimulus were modeled with a canonical hemodynamic response function. Block-level responses corresponding to each instruction type were modeled using a boxcar regressor convolved with the canonical hemodynamic response. A general linear model analysis then was used to create contrast images for each participant summarizing differences between block types, and these images were used to create group average SPM$\{t\}$ maps that were thresholded at $P < .001$ uncorrected for multiple comparisons, with an extent threshold of 5 voxels. This threshold was adopted in both experiments for regions of a priori interest shown prior work to be involved in self-referential and/or social cognitive judgments and the retrieval of episodic memories (including medial and lateral PFC, anterior and posterior cingulate/precuneus, insula, medial and anterior temporal lobe, and superior parietal cortex). Maxima are reported in ICMB152 coordinates as in SPM2.

Results

Behavioral results

Response times for judgments involving the self or a close other were made with similar speed (Self, M = 1322.3 ms; Other, M = 1367.8 ms; t = 1.66, $P > 0.10$), and both were made more slowly than Positive judgments (Positive M = 1267.0; versus Self, t = 12.55, $P < 0.05$; versus Other, t = 4.75, $P < 0.001$). Syllable and Positive judgments were made with similar speed, and Syllable

Table 2
Group activations in Experiment 1 associated with accessing knowledge about the self, a close other, or a normative assessment of trait positivity

Region of activation	Brodmann	Coordinates			*Z* score	Volume (mm^3)
		x	*y*	*z*		
Self > Syllable						
Anterior/Para-CC (MPFC)	24/32	−6	32	30	3.28	208
Other > Syllable						
Medial FG (MPFC)	32/10	0	56	−4	4.03	832
Medial FG (MPFC)	32/10	−2	56	20	3.67	184
Anterior/Para-CC (MPFC)	24/32	−8	40	34	3.41	120
Positive > Syllable						
Medial FG (MPFC)	32/10	2	52	−10	3.84	704
Medial FG (MPFC)	10	−8	52	16	3.60	576
Medial FG (MPFC)	32/10	2	48	4	3.50	256
Posterior CC/Precuneus	23	0	−56	30	3.67	1088

Notes. Contrasts were thresholded at $P < 0.001$, uncorrected, k = 5 voxels. Self > Other, Self > Positive, Other > Self and Other > Positive showed no significant regions of activation at thresholds of $P < 0.001$ or $P < 0.005$. CC = cingulate cortex. FG = frontal gyrus. MPFC = medial prefrontal cortex.

judgment response times were marginally faster than were response times for Self and Other judgments (Syllable M = 1286.4; versus Positive, $t < 1$, P = ns; versus Self, $t = 1.79$, $P < 0.10$; versus Other, $t = 2.10$, $P < 0.06$).

Imaging results

Regions associated with accessing knowledge about either the self, a close other, or assessments of normative positivity of trait words were identified in separate pairwise contrasts of either Self, Other, or Positive blocks with baseline Syllable blocks. As can be seen in Table 2 and Fig. 1, all three contrasts revealed activation in similar regions of MPFC. The Self > Syllable contrast showed activation of dorsal medial/paracingulate cortex. The Other > Syllable contrast showed activation of MPFC that overlapped and extended more rostrally than the activation shown by the Self > Syllable contrast. And the Positive > Syllable contrast showed activation of rostral MPFC that overlapped activation shown in the Other > Syllable contrast. The Positive > Syllable contrast also showed activation of posterior cingulate/precuneus.

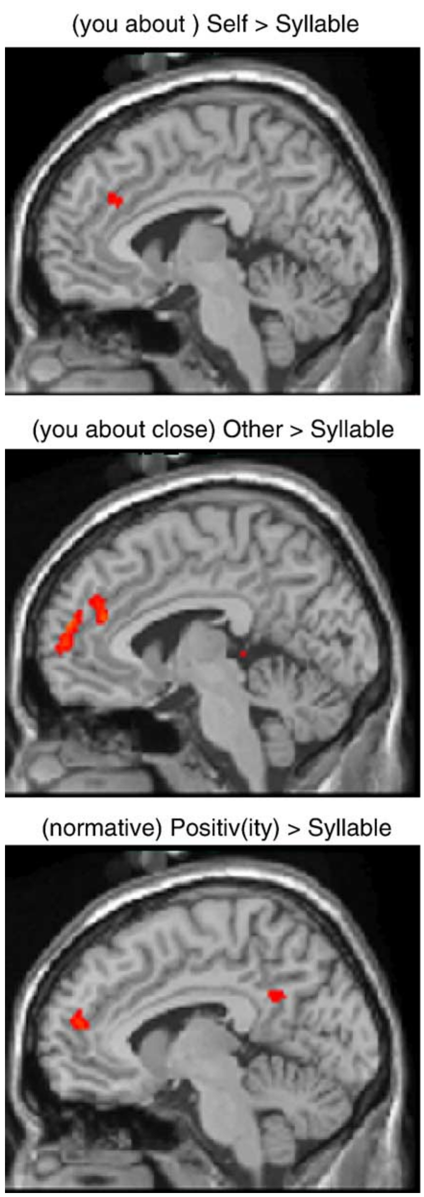

Fig. 1. Group activation results for Experiment 1. Top panel shows a region of left paracingulate cortex more active for direct self appraisals than for syllable judgments. Middle panel shows regions of paracingulate and medial prefrontal cortex more active for direct appraisals of a close other than for syllable judgments. Bottom panel shows regions of paracingulate/MPFC and posterior cingulate cortex more active for normative judgments of trait positivity than for syllable judgments.

Regions specifically associated with self-reference but not other-reference or normative assessment of trait desirability were identified in the Self > Other and Self > Positive contrasts. Neither contrast showed activation of any regions when the threshold was lowered to $P < 0.005$. At an even more liberal threshold of $P < 0.01$, activation of MPFC was not observed in either contrast.

Discussion

The results of Experiment 1 indicate that in comparison to baseline perceptual judgments of trait adjectives, direct appraisals of the self recruit MPFC, but that these regions are no different than those recruited by direct appraisals of a close other or judgments of the normative positivity of trait words. These findings suggest that prior demonstrations of MPFC activity during direct appraisals of the self may have been attributable to their comparison with direct appraisals of non-close others, such as the US President or Canadian Prime Minister, with whom one has little personal experience and whom one may be quite dissimilar (e.g., Craik et al., 1999; Kelley et al., 2002). Only one prior study has compared directly judgments about self and a close other (Schmitz et al., 2004) and, like the present findings, did not observe greater recruitment of MPFC. However, unlike that study, we did not observe greater activation for Self as compared to Positivity judgments (cf. Fossati et al., 2003).

Experiment 2

Experiment 2 directly and systematically addressed two specific questions concerning direct and reflected appraisals of the self. The first was a follow-up to the finding from Experiment 1 that the neural systems correlated with direct appraisals of the self and a close other were quite similar. Experiment 2 compares direct appraisals of the self with a close other and a non-close other to examine how activation varies with relationship intimacy (cf. Craik et al., 1999; Kelley et al., 2002). The second question concerned the relationship between direct appraisals of the self and reflected appraisals of the self made from the perspective of either the (a) close other or (b) the non-close other. Based on the findings from Experiment 1, we hypothesized that self and close other judgments – including adopting the reflected perspective of a close other on one's self – should reveal similar patterns of activation because each type of judgment relies upon access to similar/overlapping pools of semantic person knowledge (Kenny and DePaulo, 1993; Klein et al., 1997). In contrast, we hypothesized that making judgments about, or adopting the perspective of, a non-close other with whom one is less familiar than a close other could depend upon neural systems different than those involved in self judgments (Klein et al., 1997).

Methods

Participants

Sixteen participants (9 female, *M* age = 22.95 years) were recruited in compliance with the human subjects regulations of Stanford University and were compensated $20/h for their participation. All participants were screened for medications or psychological and/or neurological conditions that might influence the measurement of cerebral blood flow.

Behavioral paradigm

Participants completed six types of blocks (see Table 1) each comprised of 4 trials with positive and 4 trials with negative trait adjectives drawn from the stimulus lists employed by Craik et al. (1999). Word length, number of syllables, valence, and frequency ratings for word types were equated across six sets of 8 words each that were counterbalanced across six judgment types. Prior to the onset of each block, one of six instructional cues was presented in the center of the screen twice (using the same timing as regular judgment trials, see below) that indicated which judgment participants were to make for each trait adjective using a four-point scale. On You About Self blocks, participants were instructed to judge the extent to which the adjective described them (1 = not at all; 4 = very much). On You About Friend blocks, participants judged the extent to which the adjective described their best friend and/or relationship partner, whose identity had been specified before the experiment began. On You About Other blocks, participants judged the extent to which each adjective described a non-close individual whose identity had been specified prior to the experiment as a teaching assistant from a class taken the previous semester with whom the participant had not become friends. On Friend About You blocks, participants judged the extent to which their designated close other would judge the adjective to describe them. On Other About You blocks, participants judged the extent to which their designated non-close other would judge the adjective to describe them. On baseline Curved Lines blocks, participants judged the extent to which the adjective contained curved as compared to straight lines (1 = very few, <25% curved; 4 = very many, >75% curved). Each trial began with a fixation point presented in the center of the screen for 250 ms, followed by the stimulus adjective for 1250 ms, a rating scale for 2250 ms that included the instructional cue and labeled endpoints, and finally a 250-ms ITI. Participants made their judgments using the index through little fingers of their dominant right hand on a four button response box with the index finger always corresponding to the maximum response option for each judgment. Pre-block instructional cues were presented using the same event sequence as regular judgment trials with the exception that the fixation crossed was presented instead of a rating scale. Within each block, positive and negative words were presented in a counterbalanced pseudorandom order. To jitter the interval between trial types, a total of 48 fixation trials were distributed throughout the 36 judgment blocks, with the constraint that each block contains at least one fixation trial. Thus, for each judgment type, four blocks contained one and two blocks contained two fixation trials that were identical to curved lines trials with the exception that a fixation cross was presented instead of a trait adjective. The entire task was comprised of six functional runs each lasting 6 min 6 s. Each run included one block of each of the seven judgment types presented in pseudorandom counterbalanced order, with each block comprised of 9 or 10 trials (4 negative, 4 positive, 1–2 fixation) that were preceded by 4 s of instructional cue.

Stimuli were projected onto a screen mounted on a custom head coil that limited head motion using a bitebar. Stimulus presentation and response collection were controlled by the program Psycscope v1.2 running on a Macintosh G3 Computer. A separate training and practice session were conducted at the Psychology Department approximately 2–5 days prior to the scanning session in order to select close and non-close other individuals and to familiarize participants with the task.

MRI data acquisition

Whole brain fMRI data (28 axial slices, 4 mm thick) were collected at 3 T (GE Signa LX Horizon Echospeed Scanner) with a T2*-sensitive gradient echo spiral-in/out pulse sequence (30 ms TE, 2000 ms TR, 2 interleaves, 60° flip angle, 24-cm field of view, 64 × 64 data acquisition matrix). T2-weighted flow-compensated spin echo scans were acquired for anatomical reference using the same slice prescription (2000 ms TR; 85 ms TE).

MRI data analysis

All statistical analyses were conducted using SPM2 (Wellcome Department of Cognitive Neurology). Anatomical images first were coregistered to the mean functional image and normalized to a standard template brain. Functional images were slice time and motion-corrected, normalized to parameters derived from the anatomical normalization, interpolated to 2 × 2 × 2 mm voxels, and smoothed with a Gaussian filter (6-mm full width half maximum). To remove drifts within sessions, a high-pass filter with a cutoff period two times the block length (64 s) was applied.

A fixed effects analysis was used to model both block and event-related responses for each participant. The instructional cue proceeding each block was modeled with a canonical hemodynamic response function. Block-level responses corresponding to each instruction type were modeled using a boxcar regressor convolved with the canonical hemodynamic response. A general linear model analysis then was used to create contrast images for each participant summarizing differences between block types, and these images were used to create group average SPM$\{t\}$ maps that were thresholded as in Experiment 1 at $P < 0.001$ uncorrected for multiple comparisons, with an extent threshold of 5 voxels. Maxima are reported in ICMB152 coordinates as in SPM2.

Results

Behavioral data

Response times for judgments involving the self or a close other were made with similar speed (You About Self, M = 1240.3 ms; You About Friend, M = 1234.9 ms; Friend About You, M = 1225.4 ms; all planned pairwise t's < 1). Judgments involving a non-close other and baseline perceptual judgments of curved lines were made with equal speed, and these three judgments were made more slowly than were the three judgments involving the self or close other (You About Other, M = 1296.7 ms; Other About You, M = 1278.9 ms; Curved Lines, M = 1337.9 ms; pairwise $t(15) < 1.9$, $P > 0.08$; for comparisons with judgments involving self or close other, planned t's > 2.3, $P < 0.05$).

Imaging data

Regions involved in direct self appraisals that required accessing different types of person knowledge were identified in the three separate contrasts of You About Self, You About Friend, or You About Other trials > Curved Lines trials. Regions involved in reflected appraisals of the self from the perspective of other people were identified in contrasts of the Friend About You or Other About You trials > Curved Lines trials. All of these contrasts produced strikingly similar patterns of activation, which included regions of MPFC and anterior cingulate cortex (ACC) spanning their dorsal (BAs 8–9) to ventral (BAs 10, 25) extent, posterior cingulate cortex (PCC) and precuneus, inferior parietal cortex, and the middle and inferior temporal gyri and temporal pole. Because these patterns of activation were so similar, in order to streamline presentation of these data, the intersection of all regions activated for each of these contrasts is shown in Table 3 and Fig. 2.

Direct self appraisals recruited regions distinct from those associated with direct appraisals of a friend or non-close other. As shown in the top half of Table 4, the You About Self > You About Friend and You About Self > You About Other contrasts both activated right lateral PFC (Fig. 3a), with the latter contrast additionally activating dorsal MPFC, anterior cingulate, and superior parietal cortex (Fig. 3b). The reverse of those two contrasts identified regions more active when accessing knowledge about a friend or close other as compared to the self. As shown in the bottom half of Table 4, the You About Friend > You About Self contrast activated both dorsal and ventral portions of MPFC as well as anterior cingulate cortex, right anterior insula, and dorsolateral prefrontal and parietal cortex bilaterally, whereas the You About Other > You About Self contrast activated primarily the right inferior temporal gyrus, the parahippocampus, and the pons.

Two contrasts identified regions more active when accessing self-knowledge via direct appraisals from a first-person perspective as compared to reflected appraisals from a third-person perspective. As shown in the top half of Table 5 and Fig. 4a, the You About Self > Friend About You contrast activated posterior cingulate cortex. The You About Self > Other About You contrast also activated posterior cingulate cortex as well as the insula and superior parietal cortex. The reverse of those two contrasts identified regions more active when accessing knowledge about the self by reflected as compared to direct appraisals. As shown in the bottom half of Table 5 and Fig. 4b, the Friend About You > You About Self contrast activated right orbital, insular, and parahippocampal cortices, the left lingual gyrus and the cerebellum, whereas the Other About You > You About Self contrast activated middle and inferior temporal gyri and the pons.

Discussion

Experiment 2 addressed two important issues concerning the neural correlates of self-knowledge: whether similar systems mediate access to self-knowledge as compared to knowledge of close or non-close others, and what systems mediate direct and reflected self appraisals. In comparison to baseline perceptual judgments, activation of MPFC was associated (1) with direct

Table 3
Group activations in Experiment 2 commonly recruited by direct and reflected appraisals compared to baseline perceptual judgments

Region of activation	Brodmann	Coordinates			Z score	Volume (mm^3)
		x	y	z		
Superior FG (MPFC)	L8/9	−12	48	36	4.71	14,888
Medial FG (MPFC)	L10	−10	52	4	4.50	(L)
Superior FG (MPFC)	L8	−12	28	52	4.46	(L)
Superior FG (MPFC)	R8	18	38	44	3.58	80
Subgenual CC (MPFC)	25	−4	12	−16	4.07	104
Middle FG	L8/9	−38	10	48	3.71	120
Posterior CC	23	0	−54	24	5.14	14,376
Posterior CC	23	−8	−52	28	5.10	(L)
Posterior CC/Precuneus	23	−8	−64	14	4.83	(L)
Middle TG	L22	−48	−68	22	4.86	4648
Superior TG	L22	−60	−56	20	4.33	(L)
Middle TG	L21	−56	−48	−4	3.94	688
Middle TG	L21	−66	−38	2	3.76	(L)
Inferior TG	L21	−60	−6	−18	5.50	2136
Inferior TG	L20	−52	−8	−20	5.48	(L)
Middle TG	L21	−62	−24	−10	4.49	(L)
Inferior TG	L20	−48	4	−36	5.31	184
Temporal Pole	L20	−42	20	−30	4.34	336
Middle TG	R39	52	−62	22	4.43	1400
Middle TG	R39	56	−70	26	3.74	(L)
Superior TG	R39	60	−62	20	3.69	(L)
Inferior TG/Temp. Pole	R20	62	−10	−18	5.09	216
Lingual gyrus		12	−76	−10	3.62	48

Notes. Direct appraisals included judgments of You About Self, You About Friend, and You About Other trials. Reflected appraisals included judgments of Friend About You, and Other About You trials. Regions activated in every contrast of one of these judgments against the baseline perceptual Curved Lines judgment are listed in this Table. Contrasts were thresholded at $P < 0.001$, uncorrected, $k = 5$ voxels. (L) denotes local maximum. CC = cingulate cortex. FG = frontal gyrus. MPFC = medial prefrontal cortex.

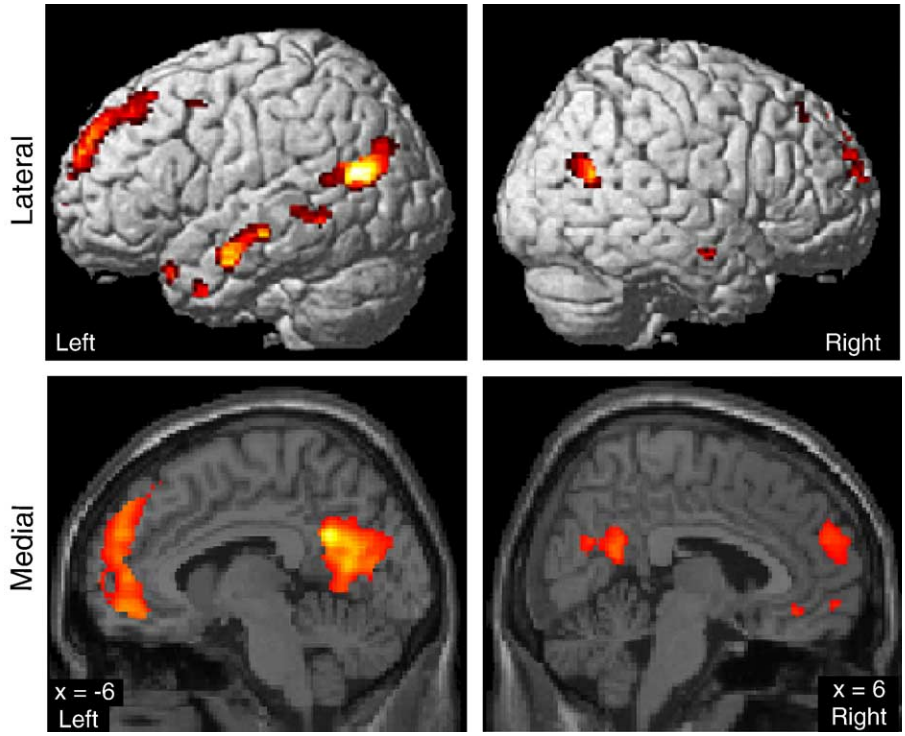

Fig. 2. Group activations common to direct and reflected appraisals in Experiment 2. Top panels show lateral and bottom panels show medial views of the cortical surface. Because these patterns of activation were so similar, in order to streamline presentation of these data, activations represented the intersection of all regions activated for each of five contrasts comparing direct appraisals (You About Self, You About Friend, and You About Other trials) or reflected appraisals (Friend About You, Other About You trials) with activation on baseline Curved Lines trials.

appraisals of trait descriptiveness for the self, close others, and non-close others – a finding that dovetails with and extends the findings of Experiment 1 – and (2) with reflected appraisals about the self made from the third-person perspective of a close or non-close other.

The striking similarity of activations for the three types of direct appraisal and two types of reflected appraisal are illustrated vividly in Table 3 and Fig. 2, which show common recruitment not only of MPFC, but of a larger network of regions including posterior cingulate/precuneus and multiple regions of the temporal lobe spanning its superior to polar extent. The dual role of these regions in direct and reflected self appraisals fits with prior work showing involvement of MPFC in mental state attribution for both self and other (Gallagher and Frith, 2003; Mitchell et al., 2004; Ochsner et al., 2004), posterior cingulate/precuneus in emotional evaluation and perspective taking (Gallagher et al., 2000; Kelley et al., 2002; Kircher et al., 2002; Lieberman et al., 2004; Maddock et al., 2003; Wicker et al., 2003), and middle and polar temporal regions in representing linguistic and semantic information useful for self-monitoring and person memory (Hashimoto and Sakai, 2003; Paller et al., 2003). Representing mental states, evaluating their valence, shifting between first and third-person perspectives, and retrieving personal attributes from memory all may play an essential role in direct and reflected appraisals.

Experiment 2 was the first to directly compare personality evaluations of the self, a close other, and a non-close other in a single study, which allows identification of regions associated with accessing knowledge about the self as compared to either highly familiar or less familiar individuals that may or may not be similar to you. As was observed in Experiment 1, activation when directly appraising one's own traits was very similar to that observed when appraising a close friend's traits. The only prior study comparing activation for self and a close other also found greater activation of right lateral PFC, but not MPFC (Schmitz et al., 2004). At a slightly relaxed threshold ($P < 0.005$), we too observed greater activity only in right lateral PFC, in a rostral region which has been associated with the evaluation of self-generated information (Christoff and Gabrieli, 2000). By contrast, prior studies comparing appraisals of self and non-close others have reported greater MPFC activation (e.g., Kelley et al., 2002). We too observed this effect, albeit once again at a slightly relaxed threshold, in MPFC regions somewhat more dorsal to those reported previously but which have been associated with self-referential processing nonetheless (for other studies showing similar foci of activation, see Table 6). The increasing recruitment of dorsal MPFC for judgments of targets more like the self suggests that this region may support high level representation and awareness of cognitive and emotional states that help differentiate self from other (cf. Gusnard et al., 2001; Lane and McRae, in press). This hypothesis is consistent with prior findings showing greater dorsal MPFC activation for judgments of one's own as compared to a non-close other's emotional state (Ochsner et al., 2004). The region of right rostral lateral PFC observed in the You About Self > You About Friend contrast was also activated in the You About Self > You About Other contrast, suggesting that it may play a general role in evaluating self-generated information pertaining to one's disposition (Christoff and Gabrieli, 2000).

Table 4
Group activations in Experiment 2 associated with direct appraisals of self as compared to direct appraisals of others

Region of activation	Brodmann	Coordinates			Z score	Volume (mm^3)
		x	y	z		
Direct appraisals of self > direct appraisals of others						
You About Self > You About Friend						
Rostrolateral PFC	10	26	42	4	2.88*	32
You About Self > You About Other						
Rostrolateral PFC	10	36	42	10	3.92	102
Inferior parietal	7	46	−54	44	3.53	232
Superior FG	6	−18	22	56	3.12	280
Superior FG (MPFC)	8	−12	40	42	2.81*	176
Anterior CC	24	8	32	32	2.69*	352
Direct appraisals of others > direct appraisals of self						
You About Friend > You About Self						
Medial FG (MPFC)	8	−12	26	40	3.99	424
Anterior CC	24/32	−8	20	36	3.15	(L)
Anterior CC	24	18	24	28	4.46	256
Subgenual CC (MPFC)	25	−6	12	−16	3.89	80
Anterior insula	13	34	26	−2	3.33	64
Precentral gyrus	4	−12	−18	72	3.49	88
Precentral gyrus	6	−36	−10	44	3.33	120
Superior FG	6	−10	2	66	3.43	120
Superior FG	6	−4	6	62	3.39	(L)
Superior FG	8	−6	16	50	3.67	224
Middle FG	9	−20	32	28	3.64	144
Middle FG	6	−38	0	24	3.56	160
Middle FG	9	−34	24	24	3.23	64
Precentral gyrus	4	10	−22	66	3.51	120
Superior FG	8/9	22	18	40	3.83	224
Middle FG	46	46	18	22	3.27	40
Middle FG	9	34	22	20	3.69	264
Middle FG	9	42	26	18	3.11	(L)
Medial parietal	7	−12	−64	62	3.68	104
Superior parietal	7	−10	−48	66	3.72	240
Parietal	40	−54	−34	48	3.64	184
Inferior parietal	7	−48	−44	44	3.41	160
Superior parietal	7	24	−64	58	3.63	184
You About Other > You About Self						
Middle TG	L22	−32	−4	26	3.41	80
Inferior TG	R20	48	14	−30	3.35	72
Inferior TG	R20	40	10	−40	3.3	48
Inferior TG	R20	46	−16	−22	3.24	48
Parahippocampus	24	−4	−10	3.42	64	

Notes. Contrasts were thresholded at $P < 0.001$, uncorrected, $k = 5$ voxels except for *, which designates $P < 0.005$ for regions shown in previous work to be related to self-reference or mental state inference. (L) denotes local maximum. CC = cingulate cortex. FG = frontal gyrus. PFC = prefrontal cortex. MPFC = medial prefrontal cortex.

Experiment 2 is also the first study to contrast direct self appraisals made from a first-person perspective with reflected self appraisals made from a third-person perspective. Direct first-person appraisals activated the midportion of the posterior cingulate more than reflected appraisals made from either the perspective of a close or a non-close other. Comparison with non-close others also revealed greater insula and inferior parietal activation. These findings are consistent with previous research showing insula and posterior cingulate activation when participants adopt a first-person as compared to third-person visual perspective on a display (Vogeley et al., 2004) and left inferior parietal activation associated with discriminating one's own actions from those of other people (Decety et al., 2002). Regions more activated for third- as compared to first-person appraisals of self-included structures associated with retrieval of episodic and semantic information as well as emotion. Thus, reflecting on a close other's opinions about you (as compared to your own opinions of yourself) activated right orbitofrontal cortex, insula and parahippocampus, which have been associated with the representation and regulation of emotional/motivational states (Beer et al., 2004; Ochsner and Feldman, 2001) and the retrieval of episodic memory (Kahn et al., 2004), respectively. Reflecting a non-close other's opinions about you activated middle and inferior temporal regions associated with storing semantic and visual memories for people and objects (Mitchell et al., 2002; Paller et al., 2003). These findings are consistent with the idea that when trying to determine what a relatively unfamiliar person might believe about you, one is more likely to rely on memories

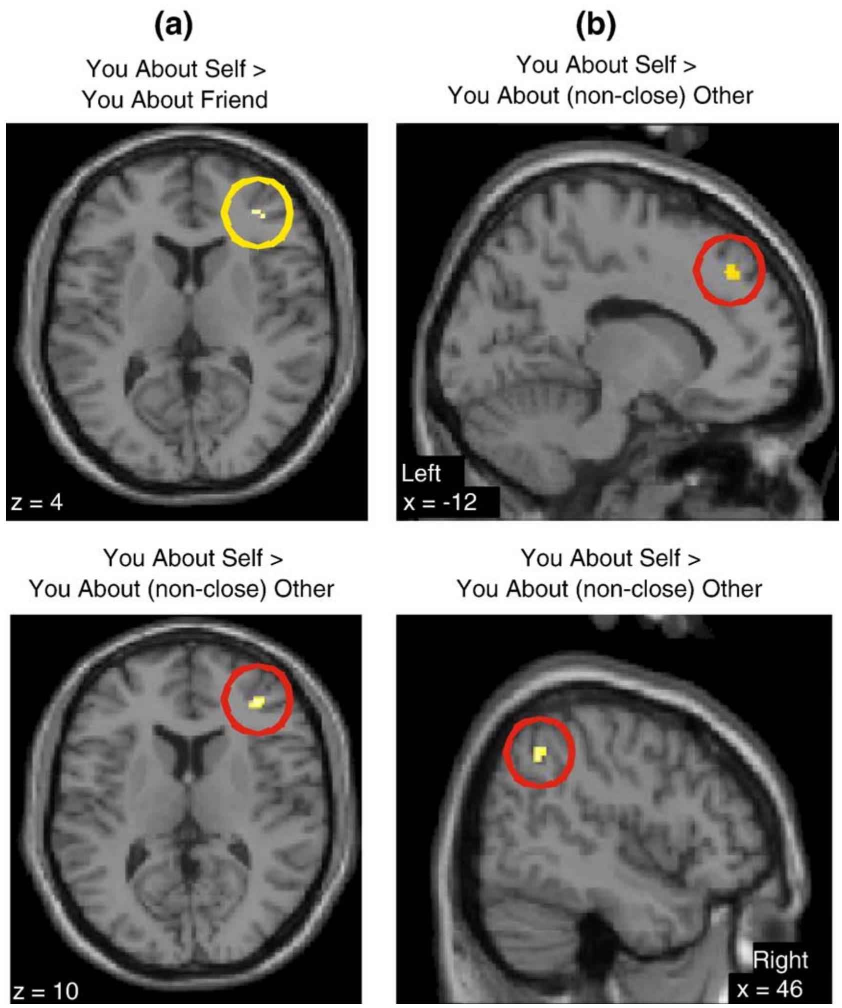

Fig. 3. Group activations specifically associated with different types of direct appraisals in Experiment 2. (a) Top panel shows region of right rostrolateral prefrontal cortex more active for direct appraisals of self as compared to a close other, defined as one's best friend and/or relationship partner. Bottom panel shows an overlapping region of right rostrolateral prefrontal cortex more active for appraisals of self as compared to a non-close other, defined as a teaching assistant the undergraduate participants had known for one semester, but with whom they had not developed a close relationship. (b) Two additional regions more active for self appraisals than for non-close other appraisals. Top panel shows dorsal MPFC activation, whereas bottom panel shows right inferior parietal activation.

of prior experiences with them.[2] Assessments of these memories may help determine what information about you would be available to another person, what beliefs they might have formed on the basis of that information, and may generate emotional responses as one attempts to resolve a clear view of one's self reflected in another's eyes. Alternatively, joint activation of structures associated with regulation, affect, and memory could reflect assessments of how much you like the other person, which could inform judgments of how much they like you back, or it could reflect self-enhancing appraisals motivated by the desire to think others view them positively. In this way, self appraisal may serve an emotion regulatory function, not unlike reappraisal of aversive events, which also involves orbitofrontal and insular regions (Ochsner et al., 2004).

[2] Response times were longer on trials involving judgments of a non-close other, which means that regions more active for contrasts involving these judgments could reflect either recruitment of processes unique to thinking about non-close others, or it could reflect engagement for a longer period of time of mechanisms also involved in other judgment types. For example, it is possible that the temporal regions identified in the contrasts of Other About You or You About Other blocks > You About Self blocks are also active when reasoning about one's self, albeit for a shorter duration of time.

General discussion

The present set of experiments began with the deceptively simple question: how do we know what were like? The results of two experiments converge to offer an interestingly complex answer.

Neural systems supporting direct and reflected self appraisals

On one hand, MPFC activation was observed in both experiments for all judgments involving direct appraisals of self, a close other, or a non-close other, as well as for all judgments involving reflected appraisals of what those others believe about you. Experiment 2 revealed additional activation associated with these judgments in posterior cingulate/precuneus and temporal cortical regions. Differential MPFC activation was observed for direct appraisals of self in comparison to non-close others but not in comparison to close others, which is consistent with the idea that similar processes may be used to support inferences about the self and those we perceive to be like us (Kenny and DePaulo, 1993; Krueger, 2003). More generally, the established association of MPFC, posterior cingulate/precuneus, and temporal regions with both self-referential and social cognitive judgments of various kinds supports the idea that these regions comprise a network important for reasoning about the states and traits of people (Table 6; Gallagher and Frith, 2003; Lieberman and Pfeifer, in press; Ochsner et al., 2004).

On the other hand, the orbitofrontal, insular, and temporal regions shown here to support a reflected third-person perspective on the self are different than the parietal and medial prefrontal regions associated in prior studies with imagining the visual perspective available to, or beliefs held by, another person (Gallagher and Frith, 2003; Ruby and Decety, 2003, 2004; Vogeley et al., 2004). One possible reason for this discrepancy has to do with differences in the content of stimuli and the judgments made about them.[3] Prior studies involving judging the mental states of others have employed visual or conceptual judgment targets that may depend more strongly upon motor imagery and visuomotor integration processes associated with parietal cortex (Decety et al., 2002; Ruby and Decety, 2003, 2004), which could explain the failure to observe parietal activation here. Additionally, these targets may have had little autobiographical and/or emotional relevance in comparison to trait adjectives, which could explain why prior studies have failed to activate regions associated with memory or emotion observed here when participants assessed what beliefs others' might hold about them.

Psychological processes supporting direct and reflected appraisals

Although the striking similarity between brain regions supporting direct and reflected appraisals is consistent with the idea that related psychological processes support them (Kenny and DePaulo, 1993; Krueger, 2003), it is important to consider at least two important questions about this apparent similarity.

The first concerns the fact that there are multiple kinds of reflected appraisals in which a person may engage, each of which may involve different types of psychological processes. For example, the present experiment examined reflected appraisals of the self concept, which likely involved memory retrieval processes, the activation of stored knowledge representations, and/or online inference processes about beliefs and mental states. As described in the preceding and following sections, activation of temporal, cingulate, and medial prefrontal regions may be related to the recruitment of these processes. By contrast, other types of reflected appraisals – such as when one attempts to, 'get a read', on audience comprehension while delivering an oral presentation – may depend instead (or additionally) upon the online assessment of non-verbal social cues. This ability has been associated with superior and inferior temporal systems different than those identified here (Allison et al., 2000).

The second question concerns the relevance of the present results to broader debates concerning the way in which we draw inferences about the beliefs, attitudes, and dispositions of other people. Some have argued that the self (i.e., one's own beliefs, attitudes, etc.) forms the basis of judging others, and that depending upon the context, we may correct for these 'egocentric' biases (e.g., Aron et al., 1992; Epley et al., 2004; Krueger, 2003). Others have argued that judgments of others involve the use of abstract person knowledge and/or theories about they way in which individuals behave in general (e.g., Gopnik and Wellman, 1992; Karniol, 2003; Perner et al., 1999). The present study was not designed specifically to discriminate between these alternatives. That being said, greater similarity between patterns of activation for appraisals of self and close as opposed to non-close others is consistent with the idea that others are judged in much the same way as the self (cf. Mitchell et al., 2005). The question of which specific computational processes support this judgment is considered in the following section.

The role of MPFC in self-reference and social cognition

The increasingly ubiquitous activation of MPFC (and nearby paracingulate cortex) across a variety of tasks ostensibly tapping self-referential, social cognitive, and other types of abilities begs the question of the exact computations carried out in this region (Gusnard and Raichle, 2001). Table 6 lists coordinates of MPFC

[3] An additional reason why the present study failed to observe medial prefrontal activation when making reflected as compared to direct appraisal has to do with the general concern that the way in which any given self-referential judgment is made differs when it is performed alone as compared to being performed in the context of other judgments (a problem common to virtually all studies investigating self-referential judgments). In the present Experiment 1, for example, it is possible that inclusion of both self referential and normative judgments led participants to engage on every trial the processes normally used to make each type of judgment alone. Thus, a participant might judge how friendly they are while the same time monitoring the extent to which friendliness is a positive trait. Conversely, a participant could judge the extent to which friendliness is a positive trait while monitoring the extent to which they themselves are friendly or would want to be friendly. In this way, the processes supporting a normative judgment, which involves reflecting the beliefs of an average person, can be recruited in combination with the processes supporting a self-referential judgment. It is possible that a similar interaction between, or parallel recruitment of, processes supporting direct and reflected appraisals took place in the context of Experiment 2. In this case, participants could be simultaneously activating processes used to judge what they think about themselves and processes used to reflect upon what their close other or non-close other might think about them. For example, when rating the extent to which a participant thinks she is friendly, she could be monitoring the extent to which her best friend/relationship partner also thinks she is friendly. Similarly, when rating the extent to which her non-close teaching assistant thinks she is diligent, she could be monitoring the extent to which she considers herself diligent. In this way, every judgment condition could involve a high degree of meta-cognitive monitoring as participants are aware of the extent to which each judgment could be made differently from a different perspective. Representing meta-self-knowledge is one function that has been proposed to explain why MPFC is recruited in self referential, social cognitive, and other types of judgment (Lieberman and Eisenberger, 2005; Ochsner and Gross, 2005). The fact that Experiment 2 used the same set of trait adjectives for all judgment conditions could have created circumstances highly conducive to engaging all of the processes simultaneously. The decision to rotate a single set of adjectives through judgment conditions was intended to model social cognitive behavioral paradigms that allow measurement of the extent to which individuals perceive themselves to be similar to close and non-close others. An unintended consequence of this methodological choice may have been an increased reliance of each judgment type on all three processes, which may have recruited MPFC, and in turn could explain why greater MPFC activation was not observed for reflected appraisals. More broadly, this could have made it less likely to observe differences in MPFC activation across conditions.

Table 5
Group activations in Experiment 2 associated with accessing self-knowledge via direct appraisals as compared to reflected appraisals

Region of activation	Brodmann	Coordinates			Z score	Volume (mm^3)
		x	y	z		
Direct first-person appraisals > reflected third-person appraisals						
You about self > friend about you						
Posterior CC/Precuneus	23	16	−56	14	2.89	64
You about self > other about you						
Mid insula	13	−42	−8	22	2.98	128
	13	−44	−12	24	2.98	(L)
Posterior CC	23	18	−22	50	3.00	40
Posterior CC	23	16	−34	50	2.95*	48
Inferior parietal	7	−26	−34	44	3.03	80
Reflected third-person appraisals > direct first-person appraisals						
Friend About You > You About Self						
Orbital FC	47	20	16	−12	3.88	248
Mid insula	13	38	−22	12	3.54	160
Parahippocampus	−30	−4	−22	3.96	184	
Superior parietal	7	−8	−52	66	4.18	144
Lingual gyrus	−20	−88	−6	3.66	80	
Cerebellum	−38	−46	−22	3.85	280	
Cerebellum	36	−50	−20	3.51	240	
Other About You > You About Self						
Middle TG	L21	−54	0	−26	4.66	856
Inferior TG	L20	−54	−10	−20	3.66	(L)
Inferior TG	R20	46	0	−34	4.42	1312
Middle TG	R21	46	−16	−18	4.25	(L)
Pons	6	−32	−32	3.59	200	

Notes. Contrasts were thresholded at $P < 0.001$, uncorrected, $k = 5$ voxels except for * and **, which designate $P < 0.005$ and $P < 0.05$ for regions shown in previous work to be related to self-reference or mental state inference. (L) denotes local maximum. CC = cingulate cortex. FG = frontal gyrus. PFC = prefrontal cortex. MPFC = medial prefrontal cortex.

and ACC activation in a group of studies involving self-referential judgments of one's current mental states or enduring traits and/or social cognitive judgments about the extent to which others possess the same kinds of states or traits. As can be seen, there is great heterogeneity in the precise coordinates activated across studies. To date, a simple theoretical framework has yet to emerge for explaining exactly why some tasks activate some regions of MPFC whereas others do not.

One suggestion is that like lateral PFC (D'Esposito et al., 2000; Miller and Cohen, 2001), ventral and dorsal regions of MPFC are involved in maintaining different types of representations necessary for task performance. On this view, ventral MPFC (roughly $z < 10$), which is interconnected with the amygdala and ventral striatum (Ongur et al., 2003; Ongur and Price, 2000), supports the representation of affective and motivational states. These representations may function as 'intuitive' feelings about the value of stimuli with respect to current goals and decisions. In contrast, dorsal regions of MPFC (roughly $z > 10$) that lack these connections may support the re-representation of this information in a symbolic format that is useful for explicitly describing and reasoning about internal states (Lane and McRae, in press; Eisenberger et al. in press; Lieberman and Eisenberger, 2005; Lieberman and Pfeifer, in press; Ochsner et al., 2004). This could explain why in Experiment 2, dorsal MPFC was recruited both when task conditions required reflected appraisals of self and when judgments required direct appraisals of self as compared to a non-close other. It can also explain dorsal MPFC involvement in theory of mind attributions and explicit ratings of current emotional states (Gallagher and Frith, 2003; Ochsner et al., 2004), as compared to ventral MPFC recruitment for more intuitive forms of self-reference as well as reward-related decision making and conditioned learning (Lieberman et al., 2004; Ochsner and Gross, 2005; Ochsner et al., 2004). In this context, it is noteworthy that all judgment types in Experiment 2 activated both dorsal and ventral MPFC in comparison to the perceptual baseline, which may be related to the recruitment of both of these types of processes.[4]

Is the self 'special'?

Socrates famously admonished his students that they should "know thyself." The present research suggests that (1) the neural systems (MPFC and rostrolateral PFC) involved in direct appraisals of self and close others may have more in common than those supporting direct appraisals of self and non-close others (Aron et al., 1992; Kenny and DePaulo, 1993), and (2) that direct and reflected

[4] Interestingly, both dorsal and ventral MPFC activity also has been found during so-called 'resting baseline' conditions in which participants can freely think about whatever they wish as compared to task conditions that require cognitive control of some kind (Gusnard and Raichle, 2001). This has led to the hypothesis that MPFC (along with other regions showing similar resting activity) continuously monitors the internal milieu (Gusnard and Raichle, 2001), and that self-referential and social cognitive judgments required by experimental tasks redirect this default-state processing system (Christoff et al., in press; Iacoboni et al., 2004; Mitchell et al., 2003). The consistent activation of MPFC for all judgment types relative to the perceptual baseline is consistent with the notion that the monitoring functions ascribed to MPFC may be recruited whenever one engages in self-appraisal.

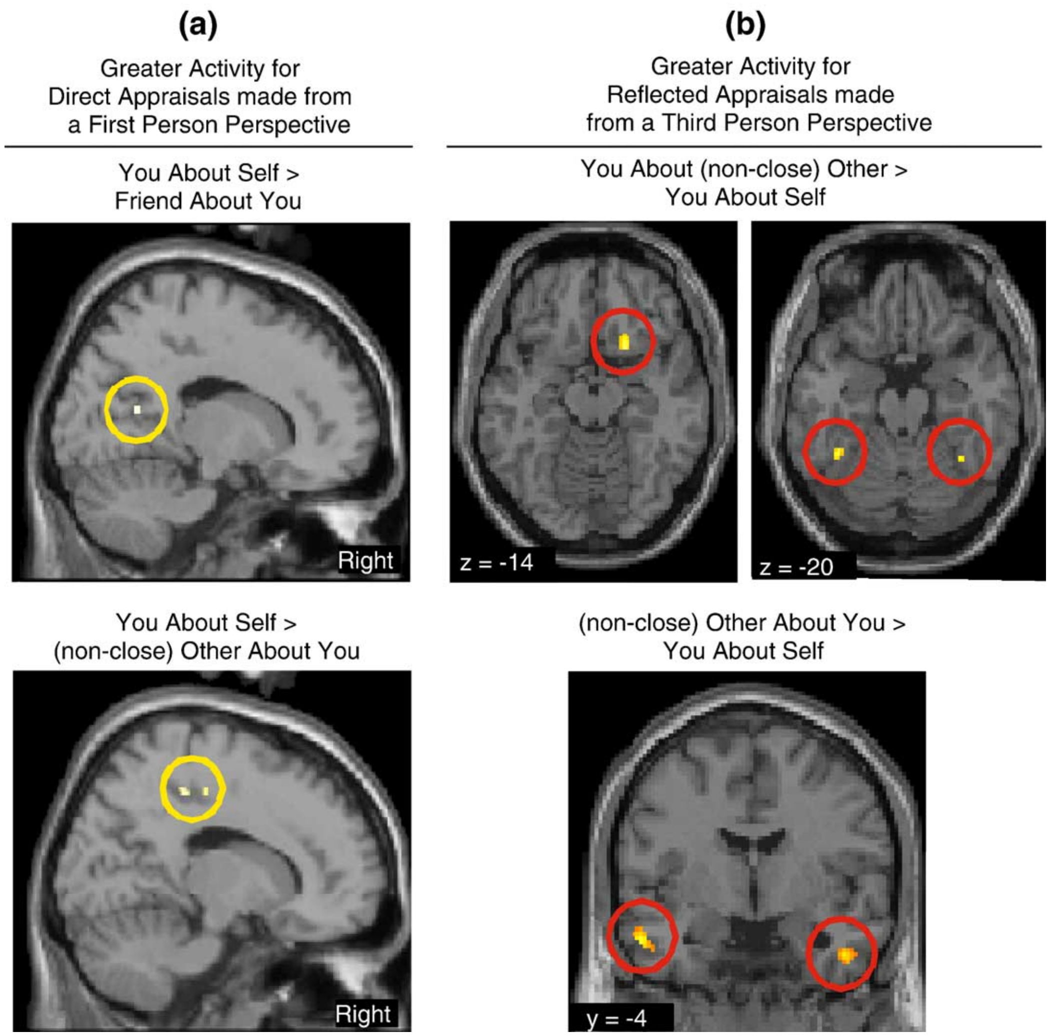

Fig. 4. Group activations specifically associated with direct as opposed to reflected appraisals in Experiment 2. (a) Top and bottom panels show regions of posterior cingulate cortex more active for first-person direct self appraisals as compared to third-person appraisals made from the perspective of a close other/friend or a non-close other. (b) Top panels show ventromedial prefrontal and inferior temporal regions more active for reflected self appraisals made from the perspective of a non-close other as compared to direct self appraisals made from one's own first-person perspective. Bottom panel shows a temporo-polar regions more active for reflected appraisals made from the third-person perspective of a non-close other as compared to direct self appraisals made from one's own first-person perspective.

appraisals of self may be thought of as two sides of the same coin, as suggested by the highly overlapping network of brain regions involved in both paths to self-knowledge. More generally, across all judgment conditions, the recruitment of MPFC and other allied regions was more similar than it was different.

It remains to be seen, however, whether this similarity holds for all types of direct and reflected appraisals and, more generally, whether similar neural systems support all types of judgments involving the self and others. A primary goal for future research should be the identification of task parameters and judgment types that recruit distinct types of computational processes involved in judgments of self and other. This work will need to address the situational (e.g., a social interaction versus a moment of self-reflection) and motivational (e.g., I want to understand my partner's feelings about me versus I need to choose a gift for him/her) contexts in which we engage each type of appraisal and recruit particular combinations of underlying neural systems.

Finally, it is important to note that accomplishment of this long-term goal may hinge upon researchers' ability to creatively and constructively integrate the theories and methods of social psychology and cognitive neuroscience. Whereas the former can help specify when, how, and with what consequences particular appraisals are made, the latter can be used to specify which neural systems may be involved. Such an integrative social cognitive neuroscience approach can be used to construct theories of self appraisals that link multiple levels of analysis (Cacioppo, 2002; Klein and Kihlstrom, 1998; Ochsner and Lieberman, 2001).

Acknowledgments

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Table 6
Medial prefrontal activation coordinates for studies involving in evaluating self attributes/beliefs or the attributes/beliefs of others

Study	*X*	*Y*	*Z*	Target	Judgment type	Contrast	Region
Ochsner, Beer et al., Experiment 1	−6	32	30	Self	Trait descriptiveness	Descriptiveness of trait for self versus counting syllables	ACC
Ochsner, Beer et al., Experiment 1	0	56	−4	NCO	Trait descriptiveness	Descriptiveness of trait for NCO versus counting syllables	vMPFC
Ochsner, Beer et al., Experiment 1	−2	56	20	NCO	Trait descriptiveness	Descriptiveness of trait for NCO versus counting syllables	dMPFC
Ochsner, Beer et al., Experiment 1	−8	40	34	NCO	Trait descriptiveness	Descriptiveness of trait for NCO versus counting syllables	ACC
Ochsner, Beer et al., Experiment 1	2	52	−10	NORM	Trait positivity	Normative positivity of trait for an average person versus counting syllables	vMPFC
Ochsner, Beer et al., Experiment 1	−8	52	16	NORM	Trait positivity	Normative positivity of trait for an average person versus counting syllables	dMPFC
Ochsner, Beer et al., Experiment 1	2	48	4	NORM	Trait positivity	Normative positivity of trait for an average person versus counting syllables	dMPFC
Ochsner, Beer et al., Experiment 2	−12	48	36	Self and Others	Trait descriptiveness	Descriptiveness of trait for self, CO, NCO, and reflected CO, NCO views of self versus percep. baseline	dMPFC
Ochsner, Beer et al., Experiment 2	−10	52	4	Self and Others	Trait descriptiveness	Descriptiveness of trait for self, CO, NCO, and reflected CO, NCO views of self versus percep. baseline	vMPFC
Ochsner, Beer et al., Experiment 2	−12	28	52	Self and Others	Trait descriptiveness	Descriptiveness of trait for self, CO, NCO, and reflected CO, NCO views of self versus percep. baseline	dMPFC
Ochsner, Beer et al., Experiment 2	18	38	44	Self and Others	Trait descriptiveness	Descriptiveness of trait for self, CO, NCO, and reflected CO, NCO views of self versus percep. baseline	dMPFC
Ochsner, Beer et al., Experiment 2	−4	12	−16	Self and Others	Trait descriptiveness	Descriptiveness of trait for self, CO, NCO, and reflected CO, NCO views of self versus percep. baseline	vMPFC
Ochsner, Beer et al., Experiment 2	8	32	32	Self	Trait descriptiveness	Descriptiveness of trait for self>NCO	ACC
Ochsner, Beer et al., Experiment 2	12	26	40	CO	Trait descriptiveness	Descriptiveness of trait for CO>self	ACC
Ochsner, Beer et al., Experiment 2	−8	20	36	CO	Trait descriptiveness	Descriptiveness of trait for CO>self	ACC
Ochsner, Beer et al., Experiment 2	18	24	−28	CO	Trait descriptiveness	Descriptiveness of trait for CO>self	ACC
Ochsner, Beer et al., Experiment 2	−6	12	−16	CO	Trait descriptiveness	Descriptiveness of trait for CO>self	ACC
Craik et al., 1999	−6	56	8	Self	Self-descriptiveness	Judge self relevance of words	vMPFC
Craik et al., 1999	6	40	28	Self	Self-descriptiveness	Judge self relevance of words	dMPFC
Fossati et al., 2003	−16	40	27	Self	Self-descriptiveness	Self referential judgment versus letter recognition control	dMPFC
Fossati et al., 2003	10	49	16	Self	Self-descriptiveness	Self referential judgment versus letter recognition control	dMPFC
Johnson et al., 2002	0	54	8	Self	Self-descriptiveness	Yes/No to self reflective versus semantic questions	vMPFC
Kelley et al., 2002	10	52	2	Self	Self-descriptiveness	Self-relevant judgments versus other relevant judgments	vMPFC
Kircher et al., 2002	−12	−22	31	Self	Self-descriptiveness	Self-descriptive versus non self-descriptive judgments	ACC
Lieberman et al., 2004	−4	58	−12	Self	Self-descriptiveness	Self-descriptiveness Js for high experience versus low experience domains	vMPFC
Lieberman et al., 2004	−10	−6	54	Self	Self-descriptiveness	Self-descriptiveness Js for high versus low experience domains P's non-schematic for trait	dMPFC
Lieberman et al., 2004	12	52	32	Self	Self-descriptiveness	Self-descriptiveness Js for high versus low experience domains P's non-schematic for trait	dMPFC
Lieberman et al., 2004	−20	52	−10	Self	Self-descriptiveness	Self-descriptiveness Js for low versus high experience domains P's non-schematic for trait	vMPFC
Lieberman et al., 2004	−22	30	−16	Self	Self-descriptiveness	Self-descriptiveness Js for low versus high experience domains P's non-schematic for trait	vMPFC
Lieberman et al., 2004	14	30	48	Self	Self-descriptiveness	Self-descriptiveness Js for high versus low experience domains P's schematic for trait	dMPFC

Table 6 (*continued*)

Study	*X*	*Y*	*Z*	Target	Judgment type	Contrast	Region
Lieberman et al., 2004	−6	54	−10	Self	Self-descriptiveness	Self-descriptiveness Js for high versus low experience domains (P's schematic for trait)	vMPFC
Macrae et al., 2004	−24	58	1	Self	Self-descriptiveness	Predicts subsequent memory after self-relevance judgment	vMPFC
Macrae et al., 2004	0	50	8	Self	Self-descriptiveness	Predicts subsequent memory after self-relevance judgment	vMPFC
Macrae et al., 2004	−9	50	8	Self	Self-descriptiveness	Judge self relevance versus perceptual baseline	vMPFC
Mitchell et al., 2005	9	57	3	Self	Judge similar other	Activation to others similar to you when forming an impression of them	vMPFC
Ruby and Decety, 2003	−24	50	−6	Self	Perspective-taking	1st person versus 3rd person conceptual perspective taking	vMPFC
Ruby and Decety, 2003	−4	68	−12	Self	Perspective-taking	1st person versus 3rd person conceptual perspective taking	vMPFC
Vogeley et al., 2001	6	54	−4	Self	Perspective-taking	Judging own intentions for imagined actions	ACC
Vogeley et al., 2001	−12	50	−4	Self	Perspective-taking	Judging own intentions for imagined actions	ACC
Ruby and Decety, 2001	14	72	10	social	Perspective-taking	3rd versus 1st person spatial perspective taking	vMPFC
Ruby and Decety, 2001	28	50	−8	social	Perspective-taking	3rd versus 1st person spatial perspective taking	vMPFC
Ruby and Decety, 2003	0	20	70	social	Perspective-taking	3rd versus 1st person conceptual perspective taking	dMPFC
Ruby and Decety, 2003	10	24	56	social	Perspective-taking	3rd versus 1st person conceptual perspective taking	dMPFC
Ruby and Decety, 2003	−8	40	52	social	Perspective-taking	3rd versus 1st person conceptual perspective taking	dMPFC
Ruby and Decety, 2003	24	48	42	social	Perspective-taking	3rd versus 1st person conceptual perspective taking	dMPFC
Mitchell et al., 2002	0	54	21	NCO	Mental state inference	Judge applicability of terms for describing people versus objects	dMPFC
Mitchell et al., 2002	3	39	0	NCO	Mental state inference	Judge applicability of terms for describing people versus objects	vMPFC
Mitchell et al., 2002	12	36	0	NCO	Mental state inference	Judge applicability of terms for describing people versus objects	vMPFC
Mitchell et al., 2004	−12	51	36	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	6	48	48	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	6	51	39	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	−9	33	57	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	0	45	36	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	6	57	33	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	12	36	57	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	−9	57	27	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	−6	51	45	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	0	39	51	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	9	63	21	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	−12	21	60	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2004	15	24	57	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Mitchell et al., 2005	9	51	36	NCO	Mental state inference	Form impression of pictured person versus judge sequence of photo presentations	dMPFC
Brunet et al., 2000	16	44	20	NCO	View moving shapes	View clips that evoke intentional versus physical causality inferences	dMPFC
Brunet et al., 2000	8	32	−4	NCO	View moving shapes	View clips that evoke intentional versus physical causality inferences	vMPFC

(*continued on next page*)

Table 6 (*continued*)

Study	*X*	*Y*	*Z*	Target	Judgment type	Contrast	Region
Brunet et al., 2000	−8	36	0	NCO	View moving shapes	View clips that evoke intentional versus physical causality inferences	vMPFC
Brunet et al., 2000	4	−4	38	NCO	View moving shapes	View clips that evoke intentional versus physical causality inferences	vMPFC
Brunet et al., 2000	−8	34	2	NCO	View moving shapes	View clips that evoke intentional versus physical causality inferences	ACC
Brunet et al., 2000	−8	36	0	NCO	View moving shapes	View clips that evoke intentional versus physical causality inferences	vMPFC
Brunet et al., 2000	4	56	44	NCO	View moving shapes	View clips that evoke intentional versus physical causality inferences	dMPFC
Brunet et al., 2000	22	38	−20	NCO	View moving shapes	View physical causality clips with characters versus without	vMPFC
Castelli et al., 2000	−4	60	32	NCO	View moving shapes	Observe complex intentional versus non-intentional control movements	dMPFC
Castelli et al., 2000	−6	58	32	NCO	View moving shapes	Observe complex intentional versus non-intentional control movements	dMPFC
Martin and Weisberg, 2003	3	52	−11	NCO	View moving shapes	View clips of social versus mechanical movements	vMPFC
Baron-Cohen et al., 1999	−9	50	20	NCO	TOM	Infer state of mind versus identify gender	dMPFC
Baron-Cohen et al., 1999	6	6	53	NCO	TOM	Infer state of mind versus identify gender	dMPFC
Baron-Cohen et al., 1999	0	47	9	NCO	TOM	Infer state of mind versus identify gender	vMPFC
Fletcher et al., 1995	0	38	24	NCO	TOM	Read theory of mind versus physical stories	ACC
Fletcher et al., 1995	−12	42	40	NCO	TOM	Read theory of mind stories versus unlinked sentences	dMPFC
Fletcher et al., 1995	−12	36	36	NCO	TOM	Read theory of mind stories versus unlinked sentences	dMPFC
Gallagher et al., 2000	−8	50	10	NCO	TOM	Read TOM versus non TOM stories	vMPFC
Gallagher et al., 2000	−10	48	12	NCO	TOM	View TOM versus non TOM stories and cartoons	vMPFC
Happe et al., 1996	−10	44	16	NCO	TOM	Read TOM versus non TOM stories	dMPFC
Saxe and Kanwisher, 2003	6	57	18	NCO	TOM	Read false belief versus false photograph stories	dMPFC
Vogeley et al., 2001	6	56	2	NCO	TOM	Judge intentions of others versus self described in vignettes	ACC
Vogeley et al., 2001	4	28	30	NCO	TOM	Judge intentions of others versus self described in vignettes	ACC
Gallagher et al., 2002	8	54	12	NCO	Interactive	Rock paper scissors game versus mentalizing human as opposed to rule-following computer	ACC
Gallagher et al., 2002	−10	50	30	NCO	Interactive	Rock paper scissors game versus mentalizing human as opposed to rule-following computer	MPFC
Gallagher et al., 2002	−2	46	14	NCO	Interactive	Rock paper scissors game versus mentalizing human as opposed to random computer	dMPFC

Notes. Articles are organized alphabetically by judgment Target and Judgment type. For judgment targets: “self” if target is the self, “NCO” if target is a non-close other, “CO” if the target is a close other, “NORM” if the goal is to estimate the (normative) opinion of an average person. For designation of region of medial prefrontal cortex activated any given study: dMPFC indicates dorsal MPFC with z coordinate >10 and including activations in Brodmann Areas 8, 9, 10, and/or dorsal 32, vMPFC indicates ventral MPFC with $z = <10$ and including activations in BAs 10, 11, 14, 25, and/or ventral 32. ACC indicates anterior cingulate cortex, which includes activations in Brodmann Areas 24 and 32. Judgment types include trait or self-descriptiveness, as in the present study; perspective taking, which includes imagining events from a 1st or 3rd person visuospatial (what do I/they see?) or conceptual (what do I/they think/feel/believe?) perspective; mental state inference, which includes judging the states or traits of depicted individuals; view moving shapes, which refers to viewing clips of moving shapes that tend to elicit spontaneous attributions of intentionality; TOM, which denotes judging vignettes or cartoons explicitly designed to require theory of mind inferences; interactive, which designates games in which participants believe they are playing in real time against or with another participant.

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