6-1-2006

# Medial Prefrontal Activity Differentiates Self from Close Others

Todd F. Heatherton
*Dartmouth College*

Carrie L. Wyland
*Dartmouth College*

C. Neil Macrae
*Dartmouth College*

Kathryn E. Demos
*Dartmouth College*

Bryan T. Denny
*Dartmouth College*

*See next page for additional authors*

## Authors

Todd F. Heatherton, Carrie L. Wyland, C. Neil Macrae, Kathryn E. Demos, Bryan T. Denny, and William M. Kelley

# Medial prefrontal activity differentiates self from close others

Todd F. Heatherton, Carrie L. Wyland, C. Neil Macrae, Kathryn E. Demos, Bryan T. Denny, and William M. Kelley

Department of Psychological and Brain Sciences, Center for Social Brain Sciences, Center for Cognitive Neuroscience, Dartmouth College, Hanover, New Hampshire, USA

A key question in psychology and neuroscience is the extent to which the neural representation of others is incorporated with, or is distinct from, our concept of self. Recent neuroimaging research has emphasized the importance of a region in the medial prefrontal cortex [MPFC; Brodmann's area (BA) 10] when performing self-referent tasks. Specifically, previous studies have reported selective MPFC recruitment when making judgments about the self relative to a familiar but personally unknown other. The present event-related functional magnetic resonance imaging study extends these findings to judgments about personally known others. Subjects were imaged while making trait adjective judgments in one of the three conditions: (i) whether the adjective described the self; (ii) whether the adjective described an intimate other (i.e., a best friend); or (iii) whether the adjective was presented in uppercase letters. Making judgments about the self relative to an intimate other selectively activated the MPFC region previously implicated in the self-processing literature. These results suggest that while we may incorporate intimate others into our self-concept, the neural correlates of the self remain distinct from intimate and non-intimate others.

## INTRODUCTION

An essential aspect of human experience is having a sense of self that is unique and distinct from others. The self encompasses such things as memory, cognition, agency, somatosensory experience, and conscious awareness. It includes a singular sense of identity, autobiographical memories of the past, and expectations and beliefs about the future. Although there has long been great enthusiasm for understanding this important psychological construct, its empirical examination has been hampered by the necessarily subjective methods of obtaining relevant data about the self (Macrae et al., 2004a). More recently, the use of neuroimaging methodologies (i.e., positron emission tomography; PET and functional magnetic resonance imaging; fMRI) has allowed researchers to resolve long-standing and vexing issues regarding the nature of self.

A fundamental question about the self is whether it has a privileged status in human cognition, such as enhancing attention to, or memory for, information that is self-relevant (Gillihan and Farah, 2005). Indeed, there is considerable evidence that information encoded with reference to the self is better remembered than information encoded about others (Rogers et al., 1977), and recent imaging studies have implicated a region in medial prefrontal cortex [MPFC;

Brodmann's area (BA)10] during tasks that encourage self-referencing (Craik et al., 1999; Johnson et al., 2002; Kelley et al., 2002; Macrae et al., 2004b; Ochsner et al., 2004; Schmitz et al., 2004).

In the Kelley and colleagues (2002) study, participants judged the trait adjectives in one of the three ways: self ('does the trait describe you?'); other ('does the trait describe George W. Bush?') and case ('is the trait presented in uppercase letters?'). Self-judgments were selectively associated with greater activation in MPFC. Moreover, the enhanced activity in MPFC likely subserved the memorial advantage afforded to self-referenced material. Macrae and colleagues (2004b) recently demonstrated that activity in MPFC can, on average, predict whether the items judged in relation to self will later be remembered or forgotten.

The extent to which we include others in our self-concept has been a topic of particular interest for social psychologists. Theories of intimacy and personal relationships might suggest that the self-reference effect is affected by the closeness of a relationship with the other used as a target. Indeed, Aron and colleagues (1991, 1996, 1999) define closeness as an extension of self into other and suggest that one's cognitive processes about a close other develop in a way so as to include that person as part of the self. Consistent with this idea, it has been demonstrated that the memorial advantage afforded to self-referenced material can be diminished or eliminated when the comparison target is an intimate other such as a parent, friend, or spouse (Bower and Gilligan, 1979; Keenan and Baillet, 1980). In a meta-analysis

of the self-reference effect in memory, Symons and Johnson (1997) found a significant overall memory difference for material encoded about the self compared with an intimate other, but the effect size was much smaller than when a familiar, but non-close, other was used for the comparison. Additionally, only personal closeness, not familiarity, influenced the effect sizes (Symons and Johnson, 1997). An open question is whether such attenuations of the self-reference effect reflect common neural substrates for judgments made about the self and personally close others.

A small number of neuroimaging studies have examined this question and have provided mixed results (Ochsner et al., 2005; Schmitz et al., 2004; Seger et al., 2004). Each study used blocked-design fMRI, and each reported similar neural activation patterns between self- and intimate-other judgments. Seger and colleagues (2004) imaged subjects while subjects made self-judgments about food preferences, friend-judgments about food preferences, and superficial judgments about food names (i.e., whether the food name contained two vowels). MPFC activity did not differ when self-judgments of food preference were contrasted directly with comparable judgments about an intimate other's food preferences. Similarly, Ochsner and colleagues (2005) imaged subjects while they were making self-judgments of personality traits (similar to Craik et al., 1999; Johnson et al., 2002; Kelley et al., 2002), close other-judgments of personality traits, social desirability judgments of personality traits, and syllable judgments of personality traits (i.e., whether the descriptor contained two syllables). Again, MPFC activity did not differ when self- and other-judgments were directly contrasted. Although Ochsner et al. (2005) and Seger et al. (2004) failed to observe differences in MPFC (i.e., BA 10) activity between self- and close-other judgments, it is difficult to interpret these findings as evidence for a shared neural representation because neither study replicated previously reported differences between self- and non-referential task conditions (e.g., Johnson et al., 2002; Kelley et al., 2002; Ochsner et al., 2004). Put simply, while MPFC activity did not differ between self and close-other conditions, it also did not differ between the self and the superficial control conditions (vowel and syllable counting) in each study. As such, it is difficult to know whether the reported null effects in MPFC for self- vs close-other judgments reflect a common functional architecture or an inability to detect differences in MPFC activity.

A more compelling case for functional homogeneity in making self- and close-other judgments can be made based on Schmitz and colleagues' (2004) finding that self-judgments and friend-judgments of trait adjectives both produced MPFC activation relative to a non-referential control condition; however, MPFC activation did not differ between self- and friend-judgments.

Given the inconsistencies and ambiguities reflected in the extant literature, as well as the importance of identifying the
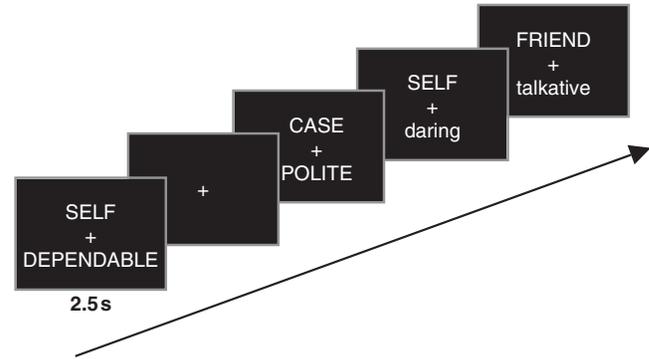


**Fig. 1** Examples of the SELF, FRIEND, CASE, and fixation trial types. Trials were randomly intermixed, and one trial was presented every 2.5 s. For each of the three judgment trial types, the 'cue' (presented above the central fixation) indicated which type of judgment to make for the trait adjective (presented below the fixation). The paradigm was identical to Kelley and colleagues (2002) with the following exception: the 'other' target used by Kelley and colleagues (George W. Bush) was changed to be an intimate other (best friend).

role of MPFC in social cognition (Amodio and Frith, 2006), we elected to use event-related fMRI to examine the extent to which MPFC activity differentiates self from close others. The present study replicated the experimental paradigm previously used by Kelley and colleagues (2002) with a single key modification: the comparison target (George W. Bush) was replaced with an intimate other (best friend) (Figure 1).

To the extent that intimate others are incorporated into our self-concept (e.g., Aron et al., 1991), we would expect similar MPFC activity when processing trait information about the self and intimate others. Conversely, to the degree that the self-concept is functionally unique relative to all familiar others regardless of personal closeness, MPFC activity should be greater for traits encoded with reference to self than for traits encoded with reference to an intimate other.

## METHOD

### Participants

A total of 30 participants between the ages of 18 and 31 years (14 male, 16 female, mean age = 24 years) were recruited from the local Dartmouth community. All the participants were strongly right-handed as measured by the Edinburgh Handedness Inventory (Raczkowski et al., 1974). The participants reported no significant abnormal neurological history and all had normal or corrected-to-normal visual acuity. They were either paid for their participation or received course credit. All participants gave informed consent in accordance with the guidelines set by the Committee for the Protection of Human Subjects at Dartmouth College. Difficulties with the fMRI-compatible optical response keys prohibited the collection of behavioral responses in eight of the 30 participants. Therefore, behavioral results reported here reflect data analyzed from the remaining 22 participants (12 male, 10 female; mean

age = 23 years). However, fMRI data was successfully collected in each of the 30 participants tested, and thus the brain imaging results reported here reflect data from all the 30 participants.

## Apparatus

Imaging was performed on a 1.5 Tesla whole body scanner (General Electric Medical Systems Signa, Milwaukee, Wisconsin) with a standard head coil. Visual stimuli were generated using an Apple G3 Laptop computer running PsyScope software (Cohen *et al.*, 1993). Stimuli were projected to participants with an Epson (model ELP-7000) LCD projector onto a screen positioned at the head end of the bore. Participants viewed the screen through a mirror. A fibre-optic, light-sensitive key press interfaced with the PsyScope Button Box (New Micros, Dallas, Texas) was used to record participants' behavioral responses. Cushions were used to minimize head movement.

## Imaging

Anatomical images were acquired using a high resolution 3D spoiled gradient recovery sequence (SPGR; 124 sagittal slices, TE = 6 ms, TR = 25 ms, flip angle = 25°, voxel size = $1 \times 1 \times 1.2$ mm). Functional images were collected in runs using a gradient spin-echo echo-planar sequence sensitive to blood oxygen level-dependent (BOLD) contrast (T2*) (TR = 2500 ms, T2* evolution time = 35 ms, flip angle = 90°, $3.75 \times 3.75$ mm in-plane resolution). During each functional run, 75 sets of axial images (27 slices; 4.5 mm slice thickness, 1 mm skip between slices) were acquired allowing complete brain coverage.

## Behavioral tasks

Prior to scanning, each subject was asked to identify a specific best friend to be used as a comparison target in the study. Participants were imaged during two functional runs while making judgments about trait adjectives. Judgments were one of three types: SELF ('Does this adjective describe you?'); FRIEND ('Does this adjective describe your best friend'); and CASE ('Is this adjective printed in uppercase letters?'). The participants indicated their responses via a left- or right-handed key press. Each trial lasted 2500 ms and consisted of a 'cue' word (either SELF, FRIEND, or CASE) presented for 2000 ms above a central fixation and a unique trait adjective (e.g., 'POLITE') presented for 2000 ms below a central fixation (Figure 1). The central fixation remained on the screen throughout the duration of each trial. All text was presented in Geneva font (white letters on a black background; letters subtended ~0.5° of visual angle). Prior to the first functional run, participants were given practice trials to familiarize them with the tasks. Practice continued until participants indicated they were comfortable with the tasks.

A total of 270 unique adjectives were selected from a pool of normalized personality trait adjectives (Anderson, 1968).

Lists were counterbalanced for word length, number of syllables, and valence (half of the words in each list were positive traits, the remaining half were negative traits). Across participants, lists were rotated through conditions such that trait adjectives that appeared in the SELF-judgment trials for one participant appeared in a different condition (FRIEND or CASE) for other participants. During each of the two functional runs, 15 SELF trials, 15 FRIEND trials, 15 CASE trials, and 30 fixation trials were pseudo-randomly intermixed such that each trial type followed every other trial type equally often. The fixation trials consisted of a central fixation point presented on the screen for 2500 ms. These trials were included to introduce 'jitter' into the time series so that unique estimates of the hemodynamic responses for the trial types of interest could be computed (Ollinger *et al.*, 2001) (see 'Data analysis' section subsequently).

Following the two encoding runs, participants were given a 'surprise' recognition memory test (not scanned). Participants viewed the 90 trait adjectives that were previously presented during the encoding scans along with 90 novel trait adjectives that had not been presented during the encoding scans. Words were presented sequentially in the center of the computer screen for 2000 ms. A fixation point (500 ms) preceded each word. For each word, the participants indicated (via left- and right-handed key presses) whether the word was old or new.

## Data analysis

The fMRI data were analyzed using Statistical Parametric Mapping software (SPM99, Wellcome Department of Cognitive Neurology, London, UK) (Friston *et al.*, 1995). For each functional run, data were pre-processed to remove sources of noise and artifact. The functional data were corrected for differences in acquisition time between slices for each whole-brain volume, realigned within and across runs to correct for head movement, and co-registered with each participant's anatomical data. The functional data were then transformed into a standard anatomical space (3 mm isotropic voxels) based on the ICBM 152 brain template (Montreal Neurological Institute) which approximates Talairach and Tournoux (Talairach and Tournoux, 1988) atlas space. Normalized data were then spatially smoothed [6 mm full-width-at-half-maximum (FWHM)] using a Gaussian kernel.

For each participant, a general linear model, incorporating task effects (modelled with a canonical set of three functions: the hemodynamic response function, its temporal derivative, and its dispersion derivative) (Friston *et al.*, 1998) and covariates of no interest (a session mean, a linear trend, and six movement parameters derived from realignment corrections) was used to compute parameter estimates ($\beta$) and t-contrast images (containing weighted parameter estimates) for each comparison at each voxel. These individual contrast

images were used in a hypothesis-driven region-of-interest (ROI) analysis focusing on MPFC.

The present study sought to examine the selectivity of MPFC during judgments about the self and an intimate other. To quantify signal change in MPFC for the three trial types in an unbiased manner, a spherical ROI (10, 52, 2; 10 mm radius) was defined based on Kelley and colleagues (2002). In this way, the same MPFC region that revealed differential activity between SELF and a non-close OTHER in our previous work could be interrogated for differences in activity when the OTHER target was altered to be an intimate other (i.e., best friend). For each participant, parameter estimates of signal change for each trial type relative to the baseline control condition (fixating a crosshair) were computed across all voxels within the MPFC ROI and examined statistically using repeated-measures analysis of variance (ANOVA).

## RESULTS

### Behavioral results

Table 1 shows behavioral performance measures for each trial type. An ANOVA showed that response latencies for encoding trials were slowest for SELF-judgments ($M = 1772$ ms) and fastest for CASE-judgments ($M = 1600$ ms), $F[2, 42] = 16.8$, $P < 0.0001$. *Post-hoc* statistical tests revealed that response latencies were significantly faster for CASE-judgments than for SELF-judgments ($F[1, 21] = 30.5$, $P < 0.0001$) and FRIEND-judgments ($F[1, 21] = 16.1$, $P < 0.0005$). The difference in response latencies between SELF and FRIEND judgments was not significant ($F[1, 21] = 2.3$, $P = 0.14$).

Accurate performance on the yes/no recognition memory test was used as an indication that successful encoding had occurred. Recognition memory performance was determined by calculating corrected recognition scores (proportion of HITS–FALSE ALARMS). An ANOVA revealed a significant main effect of trial type ($F[1, 42] = 93.8$, $P < 0.0001$). *Post-hoc* statistical tests revealed significant differences in subsequent memory for SELF and FRIEND adjectives ($F[1, 21] = 7.4$, $P < 0.01$), SELF and CASE adjectives ($F[1, 21] = 168.7$, $P < 0.0001$), and FRIEND and CASE adjectives ($F[1, 21] = 105.3$, $P < .0001$).

### fMRI results

The present study sought to determine whether the MPFC activity observed during self-reference tasks in previous work (Craik *et al.*, 1999; Johnson *et al.*, 2002; Kelley *et al.*, 2002; Macrae *et al.*, 2004b; Ochsner *et al.*, 2004; Schmitz *et al.*, 2004) would extend to the judgments about others if the target was a personally known other. As such, a hypothesis-driven analysis was performed using an *a priori*-defined ROI in MPFC (10, 52, 2; BA 10) based on Kelley and colleagues (2002). This region demonstrated a robust difference

**Table 1** Behavioral performance during encoding and recognition tasks

| Task | Encoding reaction time (ms) | Hits–false alarms |
|---|---|---|
| SELF | 1772 (29) | 0.62 (0.04) |
| FRIEND | 1725 (39) | 0.53 (0.03) |
| CASE | 1600 (27) | 0.21 (0.05) |

Standard errors are given in parentheses.
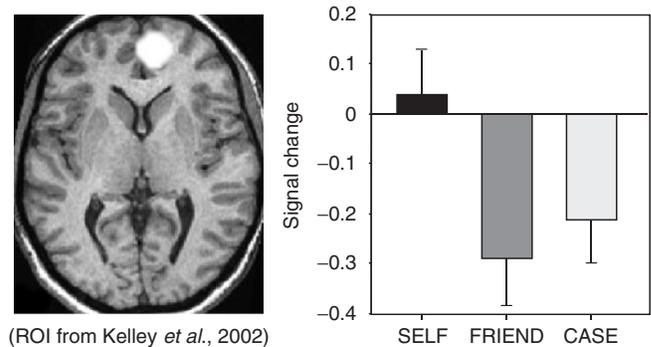


**Fig. 2** An a priori region-of-interest (ROI) in MPFC based on Kelley and colleagues (2002) was used to compute mean signal change during SELF-, FRIEND-, and CASE-judgments. Signal intensities for each condition are plotted relative to a baseline control condition (fixating a crosshair). Similar to the previous work, MPFC activity was uniquely sensitive to self judgments. Case-judgments and judgments about an intimate other produced robust decreases in MPFC activity that did not differ from each other.

between self-judgments and judgments about a familiar but not personally known other (George W. Bush) and provided an ideal test of the current question.

The targeted ROI analysis, shown in Figure 2, revealed a significant main effect of task condition ($F[2, 58] = 6.4$, $P < 0.005$), and, consistent with prior work, *post-hoc* statistical tests revealed significant differences in MPFC activity between SELF and FRIEND conditions ($F[1, 29] = 10.8$, $P < 0.005$) and SELF and CASE conditions ($F[1, 29] = 6.3$, $P < 0.05$). There was no significant difference in MPFC activity between FRIEND and CASE conditions ($F < 1$).[1]

These findings differ from findings by Schmitz and colleagues (2004) showing statistical differences in MPFC activity between self and semantic judgments, close-other and semantic judgments, but not between self and close-other judgments. To examine whether the difference across

---

1   As noted in the methods, technical problems with the optical key presses prevented behavioral data from being collected in 8 of the 30 participants tested. However, similar MPFC findings were noted when only the 22 participants for whom behavioral data were available were considered in the hypothesis-driven fMRI analysis. There was an overall main effect of task condition ($F[2, 42] = 4.4$, $P < 0.05$), and post-hoc statistical tests again revealed significant differences between SELF and FRIEND conditions ($F[1, 21] = 7.8$, $P < 0.01$) and SELF and CASE conditions ($F[1, 21] = 5.2$, $P < 0.05$). Again, MPFC activity between FRIEND and CASE conditions did not differ ($F < 1$).
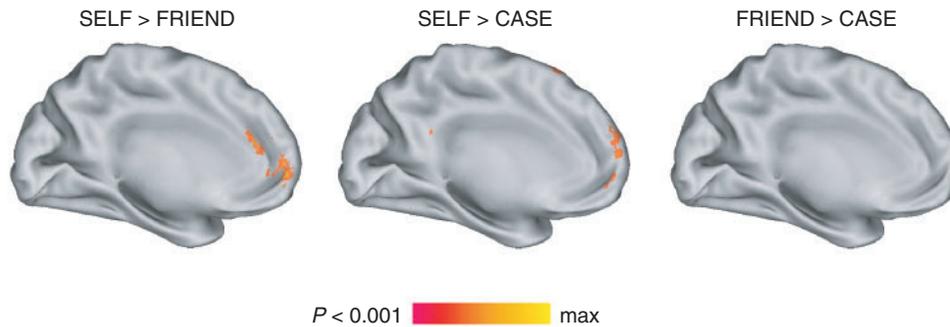
**Fig. 3** An inflated cortical rendering of the left hemisphere (Van Essen *et al.*, 2001) illustrates significant MPFC activity during direct comparisons between SELF and FRIEND (left), SELF and CASE (middle), and FRIEND and CASE (right).

**Table 2** Identification of BOLD signal changes associated with the direct comparisons between SELF and FRIEND, SELF and CASE, and FRIEND and CASE conditions

| Brain region | | T | x | y | z |
|---|---|---|---|---|---|
| **SELF > FRIEND** | | | | | |
| BA32 | Anterior cingulate gyrus | 5.73 | 0 | 39 | 17 |
| BA10 | Middle frontal gyrus | 5.34 | −9 | 55 | 3 |
| BA10 | Middle frontal gyrus | 4.61 | 6 | 58 | 3 |
| BA47 | L inferior frontal gyrus | 4.95 | −45 | 23 | −11 |
| BA47 | R inferior frontal gyrus | 4.80 | 48 | 34 | −12 |
| BA47 | R inferior frontal gyrus | 4.05 | 45 | 14 | −3 |
| BA21 | R middle temporal gyrus | 4.51 | 59 | −38 | −1 |
| BA6 | Superior frontal gyrus | 4.12 | 12 | 23 | 54 |
| BA37 | L fusiform gyrus | 3.95 | −48 | −68 | −14 |
| **FRIEND > SELF** | | | | | |
| BA7/40 | L inferior parietal lobule | 3.82 | −39 | −59 | 44 |
| Cerebellum | R cerebellum | 4.61 | 15 | −48 | −25 |
| **SELF > CASE** | | | | | |
| BA47 | L inferior frontal gyrus | 6.30 | −45 | 23 | −11 |
| BA47 | R inferior frontal gyrus | 4.36 | 50 | 23 | −11 |
| BA10 | Middle frontal gyrus | 5.70 | 9 | 58 | 0 |
| BA19 | L fusiform gyrus | 4.48 | −33 | −71 | −14 |
| BA29/30 | Posterior cingulate cortex | 4.35 | 3 | −46 | 19 |
| Cerebellum | R cerebellum | 4.60 | 27 | −74 | −24 |
| **FRIEND > CASE** | | | | | |
| BA47 | L inferior frontal gyrus | 4.34 | −30 | 31 | −24 |
| BA11 | Gyrus rectus | 4.01 | 3 | 34 | −24 |
| BA32 | Anterior cingulate gyrus | 3.65 | 0 | 14 | 46 |

Activations determined to be significant are listed along with the best estimate of their location. BA, approximate Brodmann's area location. Coordinates are from the Talairach and Tournoux (1988) atlas. Locations of the activations are determined based on the functional responses superimposed on averaged anatomical MRI images and are referenced to the Talairach atlas.

studies was a result of anatomical differences in the location of MPFC activity, we repeated our ROI analysis using a ROI defined directly from Schmitz *et al.* (2004). Specifically, a spherical ROI (10 mm radius) was centered on -4, 58, 4 [identified in the comparison of close other > semantic, in Schmitz *et al.* (2004), Table 1, p. 944]. Results revealed a significant main effect of task condition ($F[2,58] = 11.7$, $P < 0.0001$). *Post-hoc* statistical comparisons revealed significant differences in MPFC activity between SELF and FRIEND conditions ($F[1, 29] = 15.5$, $P < 0.0005$) and SELF and CASE conditions ($F[1, 29] = 19.3$, $P < 0.0001$). Again, there was no significant difference between FRIEND and CASE conditions ($F < 1$).

Although the present results focus on a targeted exploration of MPFC activity, whole-brain imaging was performed in this study. Figure 3 and Table 2 summarize significant activations in other brain regions that were observed during each direct comparison.

## DISCUSSION

The present study used event-related fMRI to assess whether making trait adjective judgments about the self relative to an intimate other preferentially activated a region of the MPFC that has been implicated in self-referential processing (Craik et al., 1999; Johnson et al., 2002; Kelley et al., 2002; Macrae et al., 2004b; Ochsner et al., 2004; Schmitz et al., 2004). Behavioral data were consistent with the predictions of the self-reference memory effect; on a 'surprise' recognition memory test given after the trait judgments were made in the scanner, participants remembered those words that were self-referenced better than those that described an intimate other or a case judgment. Further, consistent with the results of a meta-analysis by Symons and Johnson (1997), the effect size for this self-referent memory advantage was reduced in comparison with the effect size reported by Kelley and colleagues (2002), where a familiar, but not intimate, other was used (George W. Bush).

Although differences in recognition memory performance for self- and intimate other-judgments were modest, neural response differences in the MPFC as measured by BOLD signal were robust. Whereas neural responses to self-judgments in the same MPFC ROI reported in Kelley and colleagues (2002) approximated a baseline level of MPFC activity, neural responses to intimate other- and non-referential-judgments were significantly deactivated relative to baseline. This near-baseline level of activation observed in the MPFC when participants made self-judgments is consistent with the 'default mode' hypothesis of functional baseline activation proposed by Raichle and colleagues (2001). The present results indicate an MPFC response that is self-specific—namely judgments pertaining to oneself were seen to be distinct from those made for one's friend. In line with this notion, Moran and colleagues (in press) have recently demonstrated that MPFC activity tracks in a linear fashion with ratings of self-descriptiveness. That is, within the task of self-referencing, personally relevant material engages MPFC to a greater extent than material that is judged less relevant. This is true regardless of whether the self-descriptive material is positive (e.g., honest) or negative (e.g., lazy) in valence (see also Fossati et al., 2003, 2004). Likewise, Mitchell and colleagues (2005) demonstrated a positive correlation between MPFC activity and perceived self/other similarity when subjects were asked to predict the emotional state of unfamiliar faces.

These findings also fit nicely with results from Macrae and colleagues (2004b) showing that the memorial advantage afforded to self-referenced items appears to be driven by differences in MPFC activity. Specifically, activity in MPFC at the time a trait is judged is predictive of whether the trait word will later be remembered or forgotten on a subsequent surprise memory test. Here, memory for self-referenced items was superior to memory for intimate other-referenced items, and MPFC activity differentiated these two judgment types. Thus, to the degree that such memorial effects exist between self- and intimate other-judgments, one might expect MPFC activity to index the memory effect. Behaviorally, the presence or absence of a self-memory advantage over close others is variable across studies (Symons and Johnson, 1997). This variance may, in part, explain the discrepant findings on MPFC activity when self- and close-other judgments are contrasted. None of the prior work in this domain (Ochsner et al., 2005; Seger et al., 2004; Schmitz et al., 2004) explicitly tested subsequent memory for the referenced materials; future work exploring the relationship between the self-reference memory effect and MPFC activity when self is contrasted with an other may elucidate a common underlying mechanism in situations when the memorial effect is weak or absent and divergent functional anatomic differences when the memorial effect is modest or large.

The absence of memory data in the three previously published neuroimaging studies on this topic makes it difficult to reconcile the differences in MPFC activity reported here and elsewhere. A further complication is that the present study used event-related fMRI whereas all three previous studies employed blocked-design analyzes. That is, each study presented the to-be-judged material in blocks such that the task judgment was consistent across the block of items. In this way, self-judgments were made on a series of consecutive items and contrasted to the task of making other- or non-referential judgments on a separate series of consecutive items. The resulting difference image in a blocked-design analysis reflects a combination of the sustained processes related to the general situation or task setting (i.e., state effects) and the transient processes more directly related to processing of individual stimuli (i.e., item effects). That is, whereas event-related designs are only sensitive to transient changes in the hemodynamic response that are time-locked to the events of interest (item-effects), blocked paradigms are additionally sensitive to sustained signal changes that persist over time (state-effects) and are not necessarily modulated on an item-by-item basis. As such, blocked paradigms confound state- and item-related effects. That is, it is not possible to dissociate effects that are tonic and longer-lasting from effects that are stimulus-specific and wedded to current mental operations.

Given that MPFC activity is tonically active at rest (Raichle et al., 2001; Gusnard and Raichle, 2001), certain blocked-design paradigms may struggle to capture item-specific differences between conditions. Put simply, if a task block contains modest amounts of rest, either as a result of long inter-trial intervals or by the explicit inclusion of null events, the tonic MPFC response to rest may overwhelm signal differences that might be present at the item-level. For example, Ochsner and colleagues (2005) utilized a hybrid, event-related/blocked-design approach, where trials within a task block were temporally jittered to permit both

blocked- and event-related analysis of the data. Thus, task blocks for all conditions necessarily contained large amounts of rest within the blocks. When the data were examined using a blocked-design analysis, MPFC (BA 10) activity did not differ across any of the conditions. One possibility for these findings is that MPFC activity was tonically high for all conditions, thereby masking potential differences at the item-level. A flexible feature of hybrid blocked/event-related designs is the ability to separate sustained, state-effects from transient item-effects. As such, it would be interesting to know whether MPFC activity revealed transient differences between self- and close-other judgments in their study.

It is difficult to reconcile the present results with the prior study by Schmitz and colleagues (2004), particularly in light of our targeted ROI analysis using a region derived directly from their work. Whereas the present study employed an event-related design and tested 30 subjects, Schmitz and colleagues (2004) employed a blocked-design analysis and analyzed data from 18 subjects. Because both studies employed random-effects analyzes, statistical power to detect differences is driven largely by subject sample size. To the degree that signal differences between self and close-others are more subtle than self and semantic judgments or close-other and semantic judgments, such effects might only be captured via fMRI when using large sample sizes. Because Schmitz and colleagues (2004) do not report ROI-based analyzes of signal change in MPFC, it is difficult to know whether subtle differences in MPFC activity between self and close-other were present but did not reach statistical significance in a smaller sample size.

It is important to note that the present study used a rather conservative approach to address whether self- and close-other judgments produced comparable MPFC activity. The MPFC ROI was defined from an entirely independent data set (Kelley *et al.*, 2002) comparing self-judgments to judgments about a familiar but personally unknown other (George W. Bush). This region was then interrogated for replication in the current data set. The rationale for using a replication approach is based on the assumption that reproducibility of an activation across data sets is the strongest indication that the activation generalizes and is not attributable to spurious artifacts (e.g., motion).

One important caveat regarding the current findings pertains to the possibility that making judgments about close others who are even more intimate than a best friend, such as a spouse or life partner, would produce neural activation that is more commensurate with self-referent activation. Future research may shed light on this possibility.

In summary, the present study offers further evidence of a specialized role for MPFC when task demands encourage self-focused attention. Behavioral results illustrated a modest but significant memorial self-reference effect for self-referenced material (consistent with Bower and Gilligan, 1979; Keenan and Baillet, 1980), and event-related fMRI revealed significant differences in trait judgment processing between the self and an intimate other in the MPFC. Thus, although we may seem to incorporate knowledge about others into our self-concept by integrating them into our memorial self-bias, the current results suggest that the neural mechanisms subserving this representation are likely to differ from the neural representation of self-knowledge.

## REFERENCES

Amodio, D.M., Frith, C.D. (2006). Meeting of minds: the medial frontal cortex and social cognition. *Nature Reviews Neuroscience*, 7, 268–77.

Anderson, N.H. (1968). Likableness ratings of 555 personality-trait words. *Journal of Personality and Social Psychology*, 9, 272–9.

Aron, A., Aron, E.N. (1996). Self and self-expansion in relationships. In: G.J. Fletcher and J. Fitness, editors. *Knowledge structures in close relationships: a social psychological approach*. (pp. 325–344). Hillsdale, N.J.: Lawrence Erlbaum Associates, Inc.

Aron, A., Aron, E.N., Tudor, M., Nelson, G. (1991). Close relationships as including other in the self. *Journal of Personality and Social Psychology*, 60, 241–53.

Aron, A., Fraley, B. (1999). Relationship closeness as including other in the self: cognitive underpinnings and measures. *Social Cognition*, 17, 140–60.

Bower, G.H., Gilligan, S.G. (1979). Remembering information related to one's self. *Journal of Research in Personality*, 13, 420–32.

Cohen, J.D., MacWhinney, B., Flatt, M., Provost, J. (1993). Psyscope: a new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, and Computers*, 25, 257–71.

Craik, F.I.M., Moroz, T.M., Moscovitch, M., et al. (1999). In search of the self: a positron emission tomography study. *Psychological Science*, 10, 26–34.

Fossati, P., Hevenor, S.J., Graham, S.J., et al. (2003). In search of the emotional self: an FMRI study using positive and negative emotional words. *American Journal of Psychiatry*, 160, 1938–45.

Fossati, P., Hevenor, S.J., Lepage, M., et al. (2004). Distributed self in episodic memory: neural correlates of successful retrieval of self-encoded positive and negative personality traits. *Neuroimage*, 22, 1596–1604.

Friston, K.J., Fletcher, P., Josephs, O., Holmes, A., Rugg, M.D., Turner, R. (1998). Event-related fMRI: characterizing differential responses. *Neuroimage*, 7, 30–40.

Friston, K.J., Holmes, A.P., Worsley, K.J., Poline, J.P., Frith, C.D., Frackowiak, R.S.J. (1995). Statistical parametric maps in functional imaging: a general linear approach. *Human Brain Mapping*, 2, 189–210.

Gillihan, S.J., Farah, M.J. (2005). Is self special? a critical review of evidence from experimental psychology and cognitive neuroscience. *Psychological Bulletin*, 131, 76–97.

Gusnard, D.A, Raichle, M.E. (2001). Searching for a baseline: functional imaging and the resting human brain. *Nature Reviews Neuroscience*, 2, 685–94.

Johnson, S.C., Baxter, L.C., Wilder, L.S., Pipe, J.G., Heiserman, J.E., Prigatano, G.P. (2002). Neural correlates of self-reflection. *Brain*, 125, 1808–14.

Keenan, J.M., Baillet, S.D. (1980). Memory for personally and socially significant events. In: Nickerson, R.S., editor. *Attention and performance*, vol. 8, Hillsdale, NJ: Erlbaum, pp. 651–69.

Kelley, W.M., Macrae, C.N., Wyland, C.L., Caglar, S., Inati, S., Heatherton, T.F. (2002). Finding the self? An event-related fMRI study. *J Cogn Neurosci*, 14, 785–94.

Macrae, C.N., Heatherton, T.F., Kelley, W.M. (2004a). A self less ordinary: the medial prefrontal cortex and you. In: Gazzaniga, M.S., editor. *Cognitive Neurosciences III*. Cambridge, MA: MIT Press, pp. 1067–76.

Macrae, C.N., Moran, J.M., Heatherton, T.F., Banfield, J.F., Kelley, W.M. (2004b). Medial prefrontal activity predicts memory for self. *Cereb Cortex*, *14*, 647–54.

Mitchell, J.P., Banaji, M.R., Macrae, C.N. (2005). The link between social cognition and self-referential thought in the medial prefrontal cortex. *Journal of Cognitive Neuroscience*, *17*, 1306–15.

Moran, J.M., Macrae, C.N., Heatherton, T.F., Wyland, C.L., Kelley, W.M. (in press). Neuroanatomical evidence for distinct cognitive and affective components of self. *Journal of Cognitive Neuroscience*.

Ochsner, K.N., Beer, J.S., Robertson, E.R., et al. (2005). The neural correlates of direct and reflected self-knowledge. *Neuroimage*, *28*, 797–814.

Ochsner, K.N., Knierim, K., Ludlow, D.H., et al. (2004). Reflecting upon feelings: an fMRI study of neural systems supporting the attribution of emotion to self and other. *Journal of Cognitive Neuroscience*, *16*, 1746–72.

Ollinger, J.M., Shulman, G.L., Corbetta, M. (2001). Separating processes within a trial in event-related functional MRI. *Neuroimage*, *13*, 210–7.

Raczkowski, D., Kalat, J.W., Nebes, R. (1974). Reliability and validity of some handedness questionnaire items. *Neuropsychologia*, *12*, 43–7.

Raichle, M.E., MacLeod, A.M., Snyder, A.Z., Powers, W.J., Gusnard, D.A., Shulman, G.L. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences, U.S.A.*, *98*, 676–82.

Rogers, T.B., Kuiper, N.A., Kirker, W.S. (1977). Self-reference and the encoding of personal information. *Journal of Personality and Social Psychology*, *35*, 677–88.

Schmitz, T.W., Kawahara-Baccus, T.N., Johnson, S.C. (2004). Metacognitive evaluation, self-relevance, and the right prefrontal cortex. *Neuroimage*, *22*, 941–7.

Seger, C.A., Stone, M., Keenan, J.P. (2004). Cortical activations during judgments about the self and an other person. *Neuropsychologia*, *42*, 1168–77.

Symons, C.S., Johnson, B.T. (1997). The self-reference effect in memory: a meta-analysis. *Psychological Bulletin*, *121*, 371–94.

Talairach, J., Tournoux, P. (1988). *Co-Planar Stereotaxic Atlas of the Human Brain*. New York: Thieme Medical Publishers, Inc.

Van Essen, D.C., Drury, H.A., Dickson, J., Harwell, J., Hanlon, D., Anderson, C.H. (2001). An integrated software suite for surface-based analyzes of cerebral cortex. *J Am Med Inform Assoc*, *8*, 443–59.