Motivation to do Well Enhances Responses to Errors and Self-Monitoring

Humans are unique in being able to reflect on their own performance. For example, we are more motivated to do well on a task when we are told that our abilities are being evaluated. We set out to study the effect of self-motivation on a working memory task. By telling one group of participants that we were assessing their cognitive abilities, and another group that we were simply optimizing task parameters, we managed to enhance the motivation to do well in the first group. We matched the performance between the groups. During functional magnetic resonance imaging, the motivated group showed enhanced activity when making errors. This activity was extensive, including the anterior paracingulate cortex, lateral prefrontal and orbitofrontal cortex. These areas showed enhanced interaction with each other. The anterior paracingulate activity correlated with self-image ratings, and overlapped with activity when participants explicitly reflected upon their performance. We suggest that the motivation to do well leads to treating errors as being in conflict with one’s ideals for oneself.

Keywords: conflict monitoring, error monitoring, fMRI, paracingulate cortex, self-reflection, working memory

Introduction

Humans can reflect on themselves and their achievements. They can set themselves goals in relation to their expectations and monitor their progress toward them. In other words they are “self-motivated.” We know something of the brain mechanisms of motivation in other primates, for example that activity can be enhanced the greater the reward in the anterior cingulate cortex (Shidara and Richmond 2002; Amiez et al. 2006), the dorsolateral prefrontal cortex (Leon and Shadlen 1999), and the parietal cortex (Platt and Glimcher 1999). But experiments on how the behavior of animals is regulated according to external rewards cannot tell us much about how humans regulate their behavior according to their own ideals.

An early study (McClelland et al. 1953) demonstrated that the motivation of participants to perform well was influenced by the task instructions given. If the participants were told that the test they were taking measured their intelligence they used more achievement related words when writing a short story after the test. A recent study using similar instruction manipulations showed an increase in task performance, as well as an increase in cardiovascular and electrodermal reactivity (Gendolla and Richter 2005). We set out to study motivation by imaging the brain while the participants were tested on a cognitive task. The participants performed the n-back working memory task for letters (Fig. 1a). This task has been much studied in imaging experiments (Braver et al. 1997). We manipulated motivation by giving different instructions to 2 groups. We told one group (Group High_M) that we were going to assess their memory and that memory is related to intelligence. We told the other group (Group Low_M) that we were piloting the task so as to optimize certain task parameters. As revealed from participants’ ratings of motivation (Fig. 1b), the first group regarded successful performance a valuable ability.

People have beliefs about their own ability to handle a task, and so their performance is assessed partly in terms of their own internal self-evaluations (Ryan 1982; Bandura 1989), which may involve self-esteem, fear of academic standing, or social prestige. The motivation of an individual is especially stimulated when a task provides people with the opportunity to stretch their capacities (Csikszentmihalyi 1975). Studies investigating neural processes of mental state attributions have found a particular role for the anterior paracingulate cortex. Enhanced activation in this region is observed when people take a first-person perspective, judge whether adjectives relate to themselves or not, and in memory processes of items encoded in a self-relevant manner (Kelley et al. 2002; Macrae et al. 2004; Fossati et al. 2004; Ochsner et al. 2005). This led us to predict that activity in the anterior paracingulate cortex would also be increased when participants perform a cognitive task and their self-evaluation is enhanced.

In order to investigate this, we needed to match performance for the 2 groups. Unless we did so, we could not know if enhanced activity in Group High_M reflected a difference in self-involvement or a difference in performance. For this reason we used a staircase method where we altered the rate of stimulus presentation to match performance between the groups. We set the performance level to 75% correct.

Materials and Methods

Participants

Twenty-six healthy, right-handed volunteers took part in the study. In Group High_M there were 13 participants with a mean age of 23.4 ± 4.0 years (3 males, 10 females); in Group Low_M there were 13 participants with a mean age of 24.0 ± 4.3 years (5 males, 8 females). The participants gave written informed consent. The study was approved by the joint ethics committee of the Institute of Neurology and University College London Hospital, London, UK. Another 5 participants were scanned but excluded from the analysis because their performance did not reach the performance level we had set up. In addition, 2 participants were excluded before the data analysis because the manipulation failed to work. On the question asking how important it was to do well on the task, one of the participants in Group High_M only gave a rating of 3 out of 9; the other participant, from Group Low_M, gave a rating of 9 out of 9.
Behavioral Task

The participants were tested on the $n$-back task (Fig. 1a). They were given both the 3-back and the 1-back tasks for letters. Sequences of letters were presented on a screen, and for each letter the subject pressed a button. If the letter appeared 3 letters back (on the $n - 3$ runs) or one letter back (on the $n - 1$ runs) the participant made a yes response; otherwise they made a no response. The yes response was made by pressing the button corresponding to the index finger, the no response by pressing the button corresponding to the middle finger. A block consisted of 19 letters, each letter being visible for 500 ms. Within a block there were 30% hits.

The interstimulus interval (ISI) was varied between runs of the $n$-3 back task, depending on the performance of the participant. This was done to equate performance between subjects. During scanning we titrated the ISI for each participant so as to achieve a level of roughly 75% correct performance. The ISI ranged from 500 to 2500 ms, which it was decreased if it was less than 75%. To control for the rate of presentation of the letters between subjects presentation on the $n - 1$ was yoked to the previous block of trials on the $n - 3$ task. There were 4 sessions in the functional magnetic resonance imaging (fMRI) scanner. The first session was a practice session so as to familiarize the participants with the scanner environment. The following 3 sessions each consisted of 10 pairs of a block of $n$-3 and a block of $n$-1.

Before the scanning, the participants practiced each task for 10 blocks. Following the practice, we informed them about the study. Half of the participants (Group High_M) were told that we were assessing their working memory capacity and that working memory is related to intelligence. The other half of the participants (Group Low_M) were told that we were piloting a task so as to optimize certain parameters. Participants were randomly assessed into either of the 2 groups.

Given that we predicted that enhanced self-motivation would lead to activation in the anterior paracingulate cortex, we introduced an additional condition, independent of the memory task, in which members of Group High_M explicitly reflected on their task performance. The reason was that we wanted an independent measure of where the activations lay for self-reflection. A question was presented after every second $n - 3$ block. Participants answered questions related to their performance such as "My concentration was good" or "My performance was poor," whereas Group Low_M rated parameters of the task, like "The letters were easily visible" or "The task was fast." They answered the questions according to a 1-4 scale, where 1 meant not at all. The question was visible on the screen for 10 s. Within each session there were also 10 blocks of rest where a fixation cross appeared on the screen for 10 s.

After fMRI scanning the participants answered questionnaires on trait anxiety (Spielberger 1983), depression (Burns 2007), and trait anxiety (Spielberger 1983), depression (Burns 2007), as well as questions on how important it was to succeed on the task and how difficult they found the task to be. To evaluate participants' self-image in relation to being intelligent we administered rating scales where the participants rated 10 positive statements all associated with being intelligent, such as "I am clever" and "I am inventive." The ratings were done on a 1-10 scale where 1 corresponded to not at all, and 10 corresponded to yes indeed. They also rated 10 negative statements, that is, associated with being stupid, such as "I am foolish" and "I generally appear confused." In addition, for each statement the participants rated how important the attribute was to them (1-10). We calculated the product of the rating on each statement and corresponding importance factor. Subsequently, we subtracted the average score on positive statements with the average score on negative statements. High scores correspond to a positive self-image.

The group comparison tests reported in Table 1 are 2-sided $t$-tests.

Image Procedures

Imaging was performed using a 3 Tesla scanner (Siemens Allegra Erlagen, Germany). The functional images sensitive to blood oxygen level-dependent (BOLD) contrasts were acquired as gradient-echo, echo-planar $T_2$-weighted images. Image volumes of the whole brain were built up from contiguous axial slices ($n = 40$) time repetition $= 2.6 s$, time echo $= 10 ms$, matrix size $64 \times 64$, slice thickness $= 2$ mm with 1-mm gap. A high-resolution, 3-dimensional gradient-echo $T_1$-weighted anatomical image was also collected for each participant.

Table 1

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Group comparisons on behavioral measures</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Group High M (mean ± SD)</td>
</tr>
<tr>
<td>Motivation to do well on task</td>
<td>6.6 ± 1.5</td>
</tr>
<tr>
<td>Perceived task difficulty</td>
<td>6.8 ± 1.8</td>
</tr>
<tr>
<td>Performance $n - 3$</td>
<td>75.8 ± 7.5%</td>
</tr>
<tr>
<td>Reaction time on the $n$-back tasks</td>
<td>571.6 ms ± 24.1</td>
</tr>
<tr>
<td>Reaction time on question ratings</td>
<td>2.03 ± 0.15</td>
</tr>
<tr>
<td>Self-image score</td>
<td>34.8 ± 19.8</td>
</tr>
<tr>
<td>Trait anxiety score</td>
<td>44.1 ± 3.4</td>
</tr>
<tr>
<td>Depression score</td>
<td>15.0 ± 7.9</td>
</tr>
</tbody>
</table>
fMRI Data Analysis

Image processing and analysis were done using the SPM5 software (http://www.fil.ion.ucl.ac.uk/spm/), Wellcome Trust Centre for Neuro-imaging, London, UK). The first 5 volumes were discarded, and the remaining volumes realigned to the first volume to correct for head movements. Subsequently, the volumes were coregistered and normalized to the standard space (Talairach and Tournoux 1988) using the Montreal Neurological Institute reference brain. The time series were smoothed spatially with an isotropic Gaussian filter of 8-mm full width at half maximum.

The difference in motivation between the groups could either be reflected as a difference in state, that is, sustained activation throughout the experiment, or be reflected as a difference specific to the events of making either correct or error responses. To test which of these models that best explains our data we set up a mixed design (Otten et al. 2002; Dosenbach et al. 2006). For each n-back memory condition, we defined covariates for the transient activation in response to the motor responses separately for correct and incorrect responses, as well as a covariate representing each memory trial as an epoch. In addition, the question was modeled as a 5-s epoch with its onset locked to the presentation of the question. Thus, the regressors account for variance unique either to the event-related activity or the state-related activity. The transient activation was modeled with a delta function, whereas the epochs were modeled with a boxcar regressor. Statistical parametric maps of t-statistics were calculated for the 7 condition specific effects within a general linear model. All epochs and events were convolved with a canonical hemodynamic response function. The data were high-pass filtered with a frequency cut-off at 128 s.

We performed 4 contrasts of interest. We did these first for each participant separately, followed by a between subjects random-effects analysis based on summary-statistics from the subtraction images created from each subject. On the second level, we used a 2-sample t-test to compare the 2 groups. For the n-back task contrasts a regressor was included that accounted for the difference in ISI between participants.

Firstly, we were interested to see whether there was any difference between the 2 groups in sustained activity throughout the memory performance. For this, we compared the activation during the 3-back task and 1-back task.

Secondly, we were interested to see whether there was any difference between the 2 groups when performing a high load working memory task compared with a low load working memory task on correct performance (Group High_M vs. Group Low_M [3 – n correct response vs. 1 – n correct response]).

Thirdly, we investigated whether there was any difference between groups on error trials compared with correct performance (Group High_M vs. Group Low_M [errors vs. corrects]).

Last, we contrasted the activity for the ratings (Rating of performance for Group High_M vs. Ratings of the task parameters for Group Low_M). This comparison gives areas that are involved in reflecting on one’s own performance.

In addition to these contrasts of interest, we analyzed similar effects between the 2 groups in performing the 3 – n task versus the 1 – n task for correct performance using all participants where the 2 groups were modeled as separate conditions (Group High_M + Group Low_M [correct 3 – n vs. correct 1 – n]). These activations reflect performance of the working memory performance. We then used these as a mask (at a level of P < 0.01) to see whether any of the activations for the contrast of Group High_M vs. Group Low_M (errors vs. corrects) lay in task related areas (Table S1). We also created a contrast for the main effect of making errors for all participants where the 2 groups were modeled as separate conditions (Group High_M + Group Low_M [errors vs. corrects]). This was used to assess if activations specific to Group High_M lay within general error-related activity.

Finally, we looked for psychophysical interactions (PPIs) (Friston et al. 1997) as a consequence of the increased intrinsic motivation in Group High_M. We selected a seed region (6-mm radius) in the paracingulate cortex (coordinate 10 46 36) that was significant in the contrast (Group High_M vs. Group Low_M [errors vs. corrects]). We extracted the time series from this region for each participant using the first-eigen time series (principal component). The PPI regressor was calculated from the product of the mean-corrected paracingulate activity and a vector coding for the differential effect of error and correct responses. This latter vector was defined as 1 for errors made on the n = 3 and n = 1 tasks, and -1 for correct responses made on the n = 3 and n = 1 tasks. This means that our analysis of effective connectivity was specific for context-dependent paracingulate influences that occurred over and above any task effects and context-independent paracingulate influences. Thus, this PPI analysis reveals which areas show activation patterns that covary with paracingulate activity where the context is errors versus corrects. Subsequently, we asked whether there were differences between the psychophysiological interactions (PPIs) in the 2 groups. Here the 2 groups form different contexts, high in self-motivation or not. We carried out a 2-sample t-test (random-effects analysis) to compare the interactions in Group High_M and Group Low_M.

In Table 2 we report the pattern of activation that was significant on the set-level (P < 0.0001). Set-level inference refers to the statistical inference that the number of clusters observed in the activation profile is highly unlikely to have occurred by chance (Friston et al. 1996). The peaks of activation reported in the table are taken from an uncorrected threshold of P < 0.001 at voxel-level, cluster size > 5 voxels. The histograms in Figure 4 represent task-related BOLD signal changes for as estimated with the general linear model. Error bars represents the standard error. The parameter estimates are given for the voxel showing a peak difference in the between-group comparison. The baseline represents null events that were not modeled. These consist of period of rest where the participants were looking at a fixation cross in the center of the screen.

**Results**

**Behavioral Results**

We first checked that our manipulation had worked. The ratings for Group High_M on the importance of doing well on the task were significantly higher than the ratings for Group Low_M (Table 1; Fig. 1b). As a control, the participants were also asked to rate how difficult they found the task, and for this measure there was no difference between the 2 groups. Moreover, as seen in Table 1, there was no significant difference in performance level between the groups. However, Group High_M were able to achieve this level with shorter ISIs than Group Low_M (P = 0.059). This means that the instruction to Group High_M did have a behavioral effect. However, in the analysis of the imaging data, we were careful to control for this effect (see Methods and discussion).

**Table 2**

<table>
<thead>
<tr>
<th>Area</th>
<th>Side</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>t-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paracingulate cortex (32)</td>
<td>L</td>
<td>10</td>
<td>46</td>
<td>36</td>
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<tr>
<td>Pre-SMA</td>
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<tr>
<td>Cingulate sulcus</td>
<td>M</td>
<td>2</td>
<td>28</td>
<td>38</td>
<td>3.92</td>
</tr>
<tr>
<td>Cingulate sulcus</td>
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<td>46</td>
<td>22</td>
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</tr>
<tr>
<td>Superior frontal gyrus</td>
<td>R</td>
<td>20</td>
<td>42</td>
<td>60</td>
<td>3.80</td>
</tr>
<tr>
<td>Superior frontal sulcus</td>
<td>R</td>
<td>26</td>
<td>14</td>
<td>58</td>
<td>3.57</td>
</tr>
<tr>
<td>Middle frontal gyrus</td>
<td>L</td>
<td>-46</td>
<td>12</td>
<td>50</td>
<td>4.54</td>
</tr>
<tr>
<td>Middle frontal gyrus</td>
<td>L</td>
<td>-34</td>
<td>20</td>
<td>54</td>
<td>3.96</td>
</tr>
<tr>
<td>Inferior frontal gyrus (47)</td>
<td>L</td>
<td>-52</td>
<td>20</td>
<td>18</td>
<td>4.58</td>
</tr>
<tr>
<td>Inferior frontal gyrus (47)</td>
<td>R</td>
<td>-50</td>
<td>24</td>
<td>4</td>
<td>3.77</td>
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<tr>
<td>Insula</td>
<td>L</td>
<td>-34</td>
<td>10</td>
<td>20</td>
<td>3.91</td>
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<tr>
<td>Orbital frontal cortex</td>
<td>L</td>
<td>32</td>
<td>-20</td>
<td>14</td>
<td>3.52</td>
</tr>
<tr>
<td>Orbital frontal cortex</td>
<td>R</td>
<td>34</td>
<td>10</td>
<td>-18</td>
<td>3.46</td>
</tr>
<tr>
<td>Inferior temporal cortex</td>
<td>L</td>
<td>-52</td>
<td>-24</td>
<td>-28</td>
<td>3.52</td>
</tr>
<tr>
<td>Anterior temporal cortex</td>
<td>L</td>
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<td>22</td>
<td>-26</td>
<td>3.42</td>
</tr>
<tr>
<td>Cerebellum</td>
<td>L</td>
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<td>-46</td>
<td>48</td>
<td>3.43</td>
</tr>
<tr>
<td>Cerebellum</td>
<td>L</td>
<td>-30</td>
<td>-72</td>
<td>-46</td>
<td>3.65</td>
</tr>
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We were concerned that in the allocation of participants to the 2 groups, there might be differences in emotional state between the groups. To check for this, we gave self-report questionnaires on trait anxiety and depressive features in the last week. There were no differences between the groups (Table 1).

Imaging Results

n-Back Task

There was no brain areas showing higher activation for sustained activity in Group High_M compared with Group Low_M. We therefore lowered the significance level to $P < 0.001$ uncorrected, and still failed to find differences for this comparison.

For correct trials on the n-back task, there were no differences in activation between Group High_M and Group Low_M ($P < 0.001$ uncorrected). However, on error trials compared with correct trials, Group High_M showed increased activation in a wide range of prefrontal areas in contrast to Group Low_M (Table 2; Fig. 2). On the medial surface there was increased activation in the paracingulate cortex (area 32) and cingulate sulcus. On the lateral surface the enhanced activation was found in the superior frontal gyrus, middle frontal gyrus and the inferior frontal gyrus (area 47). There was also more activation in the insular cortex and the orbital frontal cortex.

There was no activity in the anterior paracingulate cortex on correct trials as assessed for the 2 groups combined (see supplementary material Table S1). Yet, this area was activated on error trials for the comparison of Group High_M with Group Low_M ($P < 0.001$). However, on error trials, Group High_M showed increased activation in a wide range of prefrontal areas in contrast to Group Low_M (Table 2; Fig. 2). On the medial surface there was increased activation in the paracingulate cortex (area 32) and cingulate sulcus. On the lateral surface the enhanced activation was found in the superior frontal gyrus, middle frontal gyrus and the inferior frontal gyrus (area 47). There was also more activation in the insular cortex and the orbital frontal cortex.

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We suggest that the anterior paracingulate activation reflects the increased tendency for group high in self-motivation to monitor their performance on error trials. In favor of this interpretation is the fact that activation in the paracingulate cortex has been widely reported during self-reflection (Amodio and Frith 2006). To confirm this association in our own results, we contrasted the activations when Group High_M answered questions on their own performance with the activations when Group Low_M answered questions about the task parameters. The differences lay in the anterior paracingulate cortex (10 46 24, $t = 2.82$), right ventral prefrontal cortex (area 47) (44 36 –4, $t = 3.42$) and the inferior temporal gyrus (66 –32 –14, $t = 4.06$).

We checked whether the paracingulate peak for reflection on one's own performance lay within the cluster that we found for the enhancement of activity in for Group High_M on error trials. We created a mask from the paracingulate cluster on the n-back task (Group High_M vs. Group Low_M [error vs. correct]). Within this mask, the activation for the ratings nearly reached statistical significance at a corrected level ($P = 0.06$). This is shown in Figure 4.

Moreover, there was a significant positive correlation between activity in the paracingulate peak (10 46 36) that was enhanced when Group High_M made errors, and self-image as rated by the participants ($r^2 = 0.39$, $P < 0.05$ one-tailed test) (Fig. 5). This correlation partialled out the effect of the ratings for motivation.

Interregional Interactions Specific to Group High_M

Further, we investigated whether there were significant interregional interactions between the anterior paracingulate cortex (10 46 36) and other areas. We investigated if there were greater interactions for Group High_M than for Group Low_M. The analysis showed that for Group High_M the activity in the anterior paracingulate cortex interacted with activity in the right inferior prefrontal cortex (area 47) (48 22 –6, $t = 4.37$) and the right orbitofrontal cortex (26 40 –12, $t = 3.87$).

The peak in the inferior prefrontal cortex was close to the peak that we found when we compared the subjective ratings for Group High_M versus Group Low_M. To show this we used the cluster that we found in the PPI (Group High_M vs. Group Low_M) as a mask for the rating contrast. The activation for the rating turned out to be significant within this cluster ($P < 0.05$ corrected). Figure 4 shows that the 2 activations are close.

Discussion

Because we were working with people rather than animals, we were able to manipulate the desire to do well so as to fit with...
made a little over 10% of errors in this condition (Group High_M 11.8%, Group Low_M 13.9%; P < 0.30). So it is not that participants in Group Low_M would have been unaware of making errors. Rather, errors took on a greater significance for members of Group High_M. Learning from errors is a critical feature of human cognition. It underlies our ability to tune behavior for optimal performance. Group High_M were primed to view their performance as being of particular importance for their self-image. We note that in a related EEG study Hajcak et al. (2005) found that manipulation of motivation influenced the ERN (error-related negativity) but not the CRN (correct response negativity). It has also been shown that error-related activity in the cingulate cortex predicts future behavioral adjustment (Kerns et al. 2004; Klein et al. 2007).

That Group High_M paid especial attention to errors is shown by the enhanced activations in the medial frontal cortex; the anterior cingulate sulcus and in the overlying pre-Supplementary motor area (preSMA) (Fig. 2). The cingulate coordinate is close to the cingulate peak at which (Carter et al. 1998) reported activity that was related to error monitoring on the Stroop task (4 25 43). It also lies just above the region to which (Debener et al. 2005) assigned the error-related negative response in a combined EEG and fMRI study (–2 20 30).

Figure 3 shows that there was activation in common for the 2 groups on error trials, however one interesting difference in activation between the groups was found in the anterior paracingulate cortex. There is extensive evidence that the anterior paracingulate cortex is activated when participants reflect on themselves (Kelley et al. 2002; Fossati et al. 2004; Macrae et al. 2004; Ochsner et al. 2005). Here we show that members of Group High_M treated errors as being in conflict with their wish to do well.

Consistent with our proposal is that there was also activation in the anterior paracingulate cortex when Group High_M rated how they were doing. The peak in the anterior paracingulate cortex was in the same region where we found enhanced activity for Group High_M on error trials (Fig. 4). Further support for the involvement of the anterior paracingulate cortex in self-monitoring was the correlation between the activity in this region and the rating of self-image reported by Group High_M (Fig. 5). The more positive self-image, the stronger was the activation of the paracingulate cortex when making errors on the memory task.

In previous studies investigating the role of the paracingulate cortex in self-reflection participants have explicitly been judging trait words (Kelley et al. 2002; Fossati et al. 2004; Macrae et al. 2004; Ochsner et al. 2005). Here we show that activity in area 32 is enhanced during a working memory task when the participants spontaneously self-reflect. This is so because people have beliefs about their own ability to handle a task, and so their performance is assessed partly in terms of their own internal self-evaluations (Ryan 1982; Bandura 1989). For example, women who are told that females perform badly on a maths task then go on to perform worse than they would otherwise do (Spencer et al. 1999). Our data do not tell us whether the enhanced response in Group High_M results from the mismatch between their performance and their intrinsic ideal, or from social embarrassment in performing poorly in public.

Our peak is located in the dorsal part of the rostral medial prefrontal cortex. The peak is similar to that reported by Ochsner et al. (2005) for reflected appraisal of self (–12 48 36),
as well as that reported by Macrae et al. (2004) when participants were judging self-relevance of trait words (19 40 32). It is also close to activations found when people make inferences about another person’s mental state (Kelley et al. 2002; Mitchell et al. 2002). It is true that many studies find enhanced activation in the ventral part of the anterior medial prefrontal cortex on self-referential tasks (Kelley et al. 2002; Fossati et al. 2004; Ochsner et al. 2004; Mitchell et al. 2005; Jenkins et al. 2008). However, the pattern of anatomical connections suggests a functional distinction between the ventral and the dorsal paracingulate cortex (Ochsner et al. 2005). Whereas the ventral part is interconnected with emotion regulating areas, the dorsal part is not (Ongur et al. 2003). Activations in the dorsal region reflect cognitive processes, as in reasoning about oneself and others (Ochsner et al. 2005). In the present study, people were told that their cognitive capacity was being evaluated, which evokes a mental state of “me as an intelligent person”. This is a cognitive rather than emotional self-schema.

The second peak for the questions lay in right inferior frontal cortex (area 47). This is the same area that showed up in the analysis of effective connectivity for the n-back task (Fig. 4). There was an interaction in Group High_M between the anterior paracingulate cortex and the right inferior frontal cortex (area 47). The activations lay in the horizontal ramus of the Sylvian fissure. Its location corresponds well to the activation reported when participants learned that they had made an error on the first shift trial on the Wisconsin Card Sorting test (Monchi et al. 2001). It is also in similar location of the activity found in a meta-study by Dosenbach et al. (2006) when participants made errors on cognitive tasks. Activation in the inferior frontal area 47 has also been reported when participants judged that negative traits were relevant to themselves, as well as that positive traits did not apply to...
study suggests that the paracingulate area 32 is closely involved in this way humans gain control over their own destiny. The present behavior according to these standards via self-reinforcement. In their development and education. They then regulate their own children acquire expectancies and standards from others during their sense of themselves as intelligent people.

propose is that the ability to reflect on oneself depends on an anterior insula surface because Amodio and Frith (2006) have suggested that functionally there is an anterior insula with the experience of negative affective states (Craig 2002; Singer et al. 2004). Activity in the lateral orbitofrontal cortex has been reported in the insula when participants were aware, as opposed to unaware, of making errors (Klein et al. 2007).

There is extensive evidence to associate activation in the anterior insula with the experience of negative affective states (Craig 2002; Singer et al. 2004). Activity in the lateral orbitofrontal cortex has been reported when participants experience punishment, e.g. monetary loss (O’Doherty et al. 2001; Kringelbach and Rolls 2004). In our study there was a significant PPI between the anterior paracingulate cortex and anterior insula proper and the orbitofrontal cortex. Activation has been reported in the anterior insula during judgments of self and others. Neuroimage. 22:1596–1604.


Figure 5. There was a significant positive correlation between activity in the paracingulate peak (10 46 36) that was enhanced when Group High M made errors, and self-image as rated by the participants. This correlation partialled out the effect of the ratings for motivation.

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