Imaging the Intentional Stance in a Competitive Game

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The "intentional stance" is the disposition to treat an entity as a rational agent, possessing particular beliefs, desires, and intentions, in order to interpret and predict it's behavior. The intentional stance is a component of a broader social cognitive function, mentalizing. Here we report a study that investigates the neural substrates of "on-line" mentalizing, using PET, by asking volunteers to second-guess an opponent. In order to identify brain activity specifically associated with adoption of an intentional stance, we used a paradigm that allowed tight control of other cognitive demands. Volunteers played a computerised version of the children's game "stone, paper, scissors." In the mentalizing condition volunteers believed they were playing against the experimenter. In the comparison condition, volunteers believed they were playing against a computer. In fact, during the actual scanning, the "opponent" produced a random sequence in both conditions. The only difference was the attitude, or stance, adopted by the volunteer. Only one region was more active when volunteers adopted the intentional stance. This was in anterior paracingular cortex (bilaterally). This region has been activated in a number of previous studies involving mentalizing. However, this is the first study suggesting a specific link between activity in this brain region and the adoption of an intentional stance. © 2002 Elsevier Science (USA)

INTRODUCTION

A growing number of functional imaging studies of normal volunteers (Baron-Cohen *et al.,* 1994; Goel *et al.,* 1995; Fletcher *et al.,* 1995; Baron-Cohen *et al.,* 1999; Gallagher *et al.,* 2000; Brunet *et al.,* 2000; Castelli *et al.,* 2000; Vogeley *et al.,* 2001, McCabe *et al.,* 2001) have sought to examine the neural substrates of mentalizing. This is our ability to explain and predict the behaviour of others by attributing independent mental states, such as thoughts, beliefs, desires, and intentions, different from our own. However, this is a complex higher cognitive function, and a ubiquitous

element of social reasoning and problem solving. Thus, it is a process that is not easily isolated. The paradigms employed in previous imaging studies of mentalizing (Baron-Cohen *et al.,* 1994; Goel *et al.,* 1995; Fletcher *et al.,* 1995; Baron-Cohen *et al.,* 1999; Gallagher *et al.,* 2000; Brunet *et al.,* 2000; Castelli *et al.,* 2000; Vogeley *et al.,* 2001 McCabe *et al.,* 2001) have used a range of tasks and conditions involving additional cognitive demands. Not surprisingly, these studies have implicated multiple neural regions, but there is also a high degree of overlap between studies. In the majority (Goel *et al.,* 1995; Fletcher *et al.,* 1995; Gallagher *et al.,* 2000; Brunet *et al.,* 2000; Castelli *et al.,* 2000, Vogeley *et al.,* 2001) three brain regions have been consistently activated (Frith, 2001). These regions are (1) the anterior paracingulate cortex (also activated in McCabe *et al.,* 2001), (2) the posterior part of the superior temporal sulcus at the temporo-parietal junction, and (3) the temporal pole. All of the previous studies, with the exception of McCabe *et al.* (2001), employed "off-line" tasks requiring the volunteer to consider a scenario and retrospectively explain the behaviour of the person or persons involved. The first aim of the current experiment was to see whether the same brain regions were activated during "on-line" mentalizing. The mentalizing task used in this study was the childrens' game "stone-paper-scissors." Playing this game required volunteers to predict the actions of their opponent (HG) in real time. This task was compared with two control tasks which did not require mentalizing. In one of these task volunteers played the same game against a computer which used simple rules and in the other they generated a random sequence of moves (see methods and Table 1). If on-line mentalizing (actively predicting another agent's actions) involves the same processes as off-line mentalizing (retrospectively explaining another agent's actions), then the critical comparison should activate regions of overlap with previous studies.

The second aim of the current study was to isolate a particular component of mentalizing; the adoption of an intentional stance (Dennett, 1971, 1991, 1996).

TABLE 1

Higher Cognitive Processes Thought to Be Engaged in Each Condition

Mentalizing	Rule solving	Random selection
Working Memory	Working Memory	Working Memory
Response selection	Response selection	Response selection
Random generation	Random generation	Random generation
Pattern Abstraction	Pattern Abstraction	
Strategy	Strategy	
Mentalizing		

That is, they would conceive of their opponent as a rational agent, possessing particular beliefs, desires, and intentions, and that this understanding would form the basis for their own actions in the game.

During acquisition of all functional data, volunteers were, without their knowledge, playing against a random sequence. The only actual differences between conditions were due to differences in the mental attitude or stance of the volunteers. The shift between playing against a computer and playing against a person, and therefore adopting an intentional stance was induced using explicit verbal instructions and through context. Thus, lead in and lead out trials, in which the volunteers were actually playing the experimenter or a computer, flanked the random sequence, lulling them into believing the manipulation. The aim of this manipulation was to influence the tendency for subjects to mentalize, whilst minimising other cognitive differences. In previous studies of mentalizing volunteers not only had to adopt an intentional stance, but also had to process different kinds of signals. In the current study the signals to be processed did not differ, only the attitude which the volunteers took towards these signals. Regions activated in common with these previous studies should therefore be specifically concerned with the stance taken rather than the kind of signals being processed.

However, there is clearly a danger that volunteers may not have responded in the manner intended. In previous imaging studies, the only assurances of the success of this type of experimental manipulation have been implicit and/or post-hoc. For example, a post-hoc finding, that activation is specific to a single region might be read as supporting the starting assumption, that the manipulation specifically affects the cognitive process under investigation. However, reverse inferences of this sort are question begging and prone to error (D'Esposito *et al.,* 1998). Therefore, we decided to seek some independent evidence concerning the effects of the experimental manipulation. This was achieved by collecting volunteers' own accounts of how they understood and experienced the different conditions. This approach was perceived as having two advantages: First, it would provide information about the demands

of the different conditions, and any differences in the strategies used by volunteers. Second, it would provide information on "what it is like" to adopt intentional and physical stances. Thus we aimed to identify the phenomenology associated with the experiment, in order to determine whether there was a general experience that could be correlated with neuronal activation.

MATERIALS AND METHODS

Nine healthy male volunteers, mean age of 32 years (range 22 to 43 years) participated in this study. They all gave informed consent and the study was approved by the local hospital ethics committee and ARSAC (UK). Each volunteer underwent 12 PET relative perfusion scans over a 2-h period. Scans were obtained using a Siemens/CPS/ECAT EXACT HR+ (model 962) PET scanner (Siemens/CTI, Knoxville, TN) with collimating septa retracted. Participants received a 20-s intravenous bolus of $H_2^{15}O$ at a concentration of 55 MBq/ml and at a flow rate of 10ml/min through a forearm cannula. Functional images were acquired over a 90-s period. All measurements were corrected for attenuation by transmission scans of 5-min duration. In addition, T_1-weighted volume acquired images was obtained for each volunteer with a Siemens Magnetom VISION MRI system operating at 2 Tesla (Siemens, Erlangen, Germany).

PET data were analyzed using statistical-parametric mapping (SPM99d) software from the Wellcome Department of Cognitive Neurology (London, UK; http://www.fil.ion.ucl.ac.uk/spm) implemented in MATLAB (Mathworks Inc., Sherborn, MA) and run on a SPARC workstation (Sun Microsystems Inc., Surrey, UK) using standardized procedures (Friston *et al.,* 1995). The images were smoothed using an isotropic Gaussian kernel (FWHM 8 mm). Condition and subject effects were estimated according to the general linear model at each voxel. To test hypotheses about regionally specific condition effects, the estimated effects were compared using linear compounds or contrasts. The resulting set of voxel values for each contrast constitutes a statistical parametric map of the *t* statistic, SPM{*t*}. The SPM{*t*} were transformed to the unit normal distribution SPM{*Z*}. We report activations significant at $P < 0.05$ corrected for multiple comparisons. In regions about which we had an apriori hypothesis, activations are considered significant at $P < 0.001$ uncorrected. The stereotactic coordinates of Talairach and Tournoux (1998) are used to report the observed activation foci. However, descriptions of the anatomical localisation of the foci were determined using averaged structural MRIs of the group and the atlas of Duvernoy (1991).

Stimuli were displayed on a monitor and presented comfortably within the volunteer's field of vision. The task consisted of a computer-based version of the play-
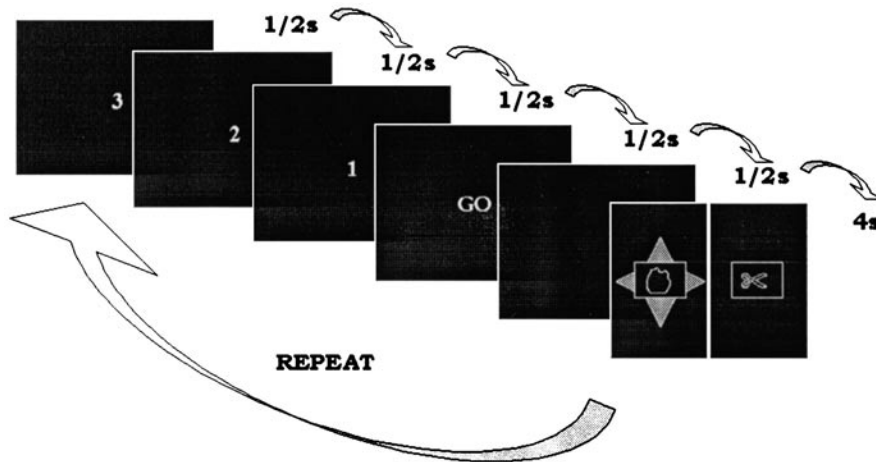
FIG. 1. Diagrammatic representation of the display and timing of the stimuli. For each trial the screen counted down 3-, 2-, 1-, at 0.5-s intervals "GO" was displayed for a further second then replaced by a blank screen for a 0.5 s. The result window was displayed for 4 s. One trial lasted 7 s. The volunteers made their selection while GO was displayed on the screen.

ground game "stone, paper, scissors!" Stone beats scissors, paper beats stone, and scissors beats paper. In this version the selection was made on a keyboard and the choice displayed as an icon in the result window (see Fig. 1). The result window showed the volunteer's choice on the left above the word "YOU" and his opponent's on the right above the word "PLAYER." A star displayed behind the winning choice. In the event of a draw a diamond was displayed behind each choice to maintain the visual input.

If the volunteer failed to make a selection, their screen remained blank and the opponent was credited with a win. Each volunteer played a total of 12 "games," 1/scan run—four games of each condition. Each "game" consisted of 30 trials. Instructions were given prior to scanning and training games were played to familiarise the volunteers with the display and timing (Fig. 1), the response keyboard and the rules of each condition.

Since some people believe that the most effective method of play is to be as random as possible volunteers were explicitly instructed to try and out wit and second guess their opponent, when the condition was playing against a person.

In the other two conditions volunteers played against a computer. In the rule solving condition the computer based it's response on a simple rule which was related to the volunteer's previous responses. Thus the computer's selections were (a) the same as the volunteer's last response, (b) the response which would have beaten the volunteer's last response, or (c) the response which would have lost to the volunteer's last response. The rules were then to always use one of these selections (e.g., a a a a a, etc.) or to alternate between two of them (e.g., a b a b a b, etc.). The rule that the computer used changed a few times during the run. Volunteers were warned of this and asked to re-

adjust to the new rule when they realised it had changed. Volunteers were instructed that the aim of the mentalizing and rule solving conditions was to win as many trials as possible, thus the volunteer's score was calculated and displayed at the end of each run.

During the random selection condition the computer randomly generated its choice. The volunteer was asked to respond randomly but not to choose the same response as the computer had on the previous trial. The stars and diamonds indicating win, lose or draw were still displayed to maintain visual input but the volunteer was not given a score. This condition acted as a baseline task.

To isolate activity associated with the intentional stance a random sequence was inserted into each mentalizing and rule solving game, which coincided with and lasted the duration of the critical scan window. Thus the volunteers played 15 lead-in trials against their anticipated opponent followed by 10 randomly generated trials and 5 lead-out trials against the opponent. The purpose of the lead-in and lead-out trials was to convince the volunteers of the presence of a particular opponent. A continuous random sequence throughout the game may have been detected. Volunteers were not informed of the random sequence. Before commencement of each set of trials the volunteer was informed of the condition and reminded of the appropriate rules. It was stressed to the volunteers that they should not stereotype their responses in any of the conditions.

Verbal report data were collected in two phases. First, four pilot subjects were given unstructured interviews during a development phase. These data were used to refine the experimental paradigm and instructions, and to identify key questions for interview during the scanning phase. Immediately after the experiment, the volunteers were interviewed for 10–20 min.

The interviews were conducted semistructurally, following a common list of questions, yet leaving the volunteers room to find their own wordings and leaving the interviewer room to follow up on particular aspects. The interviews were taped and subsequently transferred to computer. The interviews were coded and annotated by two researchers using HyperResearch 2.03 (ResearchWare, MA). The coders had no knowledge of the scanning data. Subsequently, central parts of the interviews were transcribed for further analysis.

RESULTS

Verbal Reports

The principle observations from the verbal reports collected after scanning were as follows:

1. No volunteer realized that a random sequence was inserted during the scanning window, in the computer or mentalizing conditions.

2. In discussing the mentalizing condition, volunteers unanimously depicted the opponent as an intentional agent. They all described guessing and second guessing their opponent's responses, and attempting to identify characteristic patterns of behaviour in the opponent. To a lesser extent, they described their opponent as reading their own patterns of behavior. Volunteers spoke of strategies for response, which they related to imagined mental states of their opponent. However, there was one exceptional volunteer who claimed that the "nature of the game" was such that the notion of strategy did not make much sense since any strategy would immediately be detected by the opponent. Nonetheless, this volunteer did report that he performed worse against the person than against the computer and that he felt particularly disappointed when he lost against the person. Thus, in spite of the apparent similarity in strategy he experienced a difference when playing against a person rather than a computer.

3. There was considerable variation in volunteers' descriptions of the computer condition. The instructions stated that the computer would follow rules that related its current response to the previous response of the volunteer. Some volunteers attempted to identify these simple rules, and occasionally succeeded. They described the computer as in principle very predictable, although the rules it used could not always be detected. Others found the computer's responses more baffling, and contrasted it with playing the experimenter—whose actions they felt they could understand and "go along with." These volunteers elaborated their own, generally vague, conceptions of what the computer was doing. One volunteer imagined that the computer was engaged in extremely complex multilayered analyses of his patterns of response.

4. A number of volunteers used mentalistic language when depicting the computer. However, use of mentalistic language is not necessarily a good indicator of adopting an intentional stance. The clearest difference between physical and intentional stances is the subjective sense of another's presence. When volunteers were asked to describe differences between computer and mentalizing conditions, two consistent findings emerged. First, all volunteers reported that the two conditions "felt" distinctly different and that the mentalizing condition involved a feeling of interacting with another person whose actions one could "go along with." Second, they found the computer condition more time pressured and strenuous than the mentalizing condition. Volunteers explained this by reporting that they felt they could not keep up with a computer, but that when they were playing another person the timing was not so critical, since their opponent would have the same amount of time as them.

Verbal reports of this sort are not appropriate for quantitative analysis. However, they may assist in the interpretation of the main findings. Two points are particularly relevant. First, the reports testify that the conditions were experienced as quite different, although the actual stimuli in the scanning window were the same. The experience of playing the person was described as an interaction with a rational agent with distinct beliefs, intentions, and desires. This contrasted with the computer which was not given these attributions but was described as acting according to a design. The reports thereby support the claim that volunteers did indeed take "an intentional stance" when playing against a person. Second, volunteers clearly experienced the computer condition to be more demanding than the mentalizing condition. This finding is significant, given the suggestion that paracingulate activation may be associated with a subjective sense of effort (Bush *et al.,* 2000).

Performance Measures

Performance measures showed that there was no significant difference ($t(8) = 0.6$, $P = 0.5$) between the conditions during the critical scan window (percentage mean wins; mentalizing = 33.1, rule solving = 31.2); (percentage mean losses; mentalizing = 32.2, rule solving = 34.7; percentage mean draws; mentalizing = 34.7, rule solving = 33.9) or during the prescan trials ($t(8) = 1.9$, $P = 0.08$) (percentage mean wins; mentalizing = 24.4, rule solving = 37.3; percentage mean losses; mentalizing = 30.9, rule solving = 34.3; percentage mean draws; mentalizing = 44.7, rule solving = 28.4). There was also no significant difference between these conditions in the number of failures to respond during the critical scan window ($t(8) = 0.4$, $P = 0.7$; mean; mentalizing = 1, rule solving = 1.22) or during the prescan trials ($t(8) = 1.069$, $P = 0.3$; mean;

TABLE 2

Regions of Increased Brain Activity Associated with Mentalizing Compared
with (i) Rule Solving and (ii) Random Generation

	Putative Brodmann area	Coordinates			Z value
		x	y	z	
(i) Mentalizing vs rule solving					
Anterior paracingulate cortex	32	8	54	12	3.47
Anterior paracingulate cortex	32/9	−10	50	30	3.27
(ii) Mentalizing vs random generation					
Anterior paracingulate cortex	32	−2	46	14	3.24
R inferior frontal cortex	47	38	24	−20	3.83
Cerebellum		30	−80	−30	4.36
Cerebellum		−26	−80	−26	4.50

mentalizing = 1.22, rule solving = 1.88). These results confirm that the only difference between the conditions lay in the stance of the volunteer.

Brain Activity

The critical comparison, looking at where brain activity was greater in the mentalizing condition than the computer condition, revealed only one region of significant difference; the most anterior portion of the paracingulate cortex bilaterally; Brodmann area 32/9 (see Table 2 and Fig. 2). No further regions appeared when the statistical threshold was lowered to $P = 0.1$. The same region activated significantly when mentalizing was compared with random generation. In addition, this comparison revealed activity in the right inferior frontal cortex (BA 47) and the cerebellum (Table 2). The right inferior frontal cortex was also seen to be significantly more active in the computer condition as compared with random generation. No activity was seen in the paracingulate cortex in this comparison
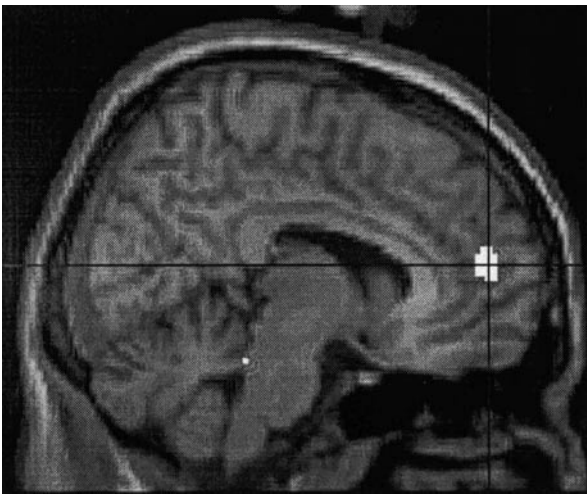

FIG. 2. An SPM showing activation in the most anterior portion of the paracingulate cortex elicited in the contrast of mentalizing versus rule solving.

even when the threshold was lowered to $P = 0.1$. As was expected no regions were significantly more active in the computer condition than in the mentalizing condition.

DISCUSSION

The Roles of the Regions Activated in Studies of Mentalizing

Our main comparison, of the mentalizing condition with the computer condition, revealed activity in just one of the three regions consistently observed in previous functional imaging studies of mentalizing in normal volunteers (Goel *et al.,* 1995; Fletcher *et al.,* 1995; Gallagher *et al.,* 2000; Brunet *et al.,* 2000; Castelli *et al.,* 2000, Vogeley *et al.,* 2001); the anterior paracingulate cortex. The tasks used in these previous studies were associated with many aspects of mental state attribution. For example, they involved desires, intentions, thoughts and knowledge (Fletcher *et al.,* 1995; Brunet *et al.,* 2000; Gallagher *et al.,* 2000). On the other hand, in these tasks the mentalizing was done off-line and did not involve direct interaction with another person. Furthermore these tasks did not involve competition or winning and losing. The common feature of the tasks used in the present and these previous studies is the requirement to take an intentional stance; in other words to use the available information to discover the beliefs, intentions and desires of another person. Of particular relevance is the recent study by McCabe *et al.* (2001). As in the present study, McCabe *et al.* (2001) used on on-line task, which involved anticipating the behavior of another player. However, unlike the present study the task was cooperative rather than competitive. In the critical comparison McCabe *et al.* (2001) also observed activity in anterior paracingulate cortex at coordinates very similar to those observed in the present study ($x = 5$, $y = 52$, $z = 10$ from Fig. 4 in McCabe *et al.,* 2001).

The absence of activity in the right temporo-parietal cortex in the present study is interesting as this region has been prominent in most previous imaging studies of mental state attribution (Goel *et al.,* 1995; Fletcher *et al.,* 1995; Baron-Cohen *et al.,* 1999; Gallagher *et al.,* 2000; Brunet *et al.,* 2000; Castelli *et al.,* 2000). However, this region is not necessarily associated with mentalizing per se. For instance, Brunet *et al.* (2000) found bilateral temporal activation to be associated with the appearance of people in the cartoon strips even when it was not necessary to consider their intentions. In our previous study (Gallagher *et al.,* 2000) we used a story comprehension task and humorous cartoons to compare mentalizing in both the verbal and the nonverbal domains. We found bilateral temporoparietal activation (particularly on the right) when the mentalizing conditions were compared with equivalent non-mentalizing conditions and a low-level control condition. However, we also found an activation in this region, although less strong, when the non-mentalizing conditions were compared with the low-level control, thus indicating that these are not uniquely associated with mentalizing. The *R* temporoparietal cortex has also been activated in previous imaging studies involving the perception of biological motion (Bonda *et al.,* 1996; Calvert *et al.,* 1997; Puce *et al.,* 1998; Grezes *et al.,* 1998, 1999). A common factor of these studies is that they all involve some explicit representation of behavior, either directly or by verbal description. The behavior of others is the principal source of information for making attributions about their mental states, but such information is only used in this way when we adopt an intentional stance. It seems plausible that this region of temporoparietal cortex is activated by the presentation of signals important for mentalizing even when the subject is not adopting an intentional stance. In contrast, anterior paracingulate cortex is activated when the subject adopts an intentional stance even when there are no additional verbal or visual cues to assist mentalizing. Presumably the region of the temporal pole also activated in many studies of mentalizing has a similar role to temporoparietal junction; it is concerned with signals important for mentalizing, but not with mentalizing per se.

The Role of Anterior Paracingulate Cortex

There is evidence from studies of patients with lesions that intact frontal cortex, in particular the medial frontal region, is necessary for good performance of mentalizing tasks. Rowe *et al.* (2001) found that patients with frontal lesions had difficulties with mentalizing tasks and these difficulties were independent of problems they had with traditional executive tasks. Stuss *et al.* (2001) also found that patients with frontal lesions had difficulties with mentalizing tasks. In particular patients with medial frontal lesions (especially on the right) were unable to detect the deception of a protagonist, a classic task requiring mental state attribution. As yet we have no information about the effects of lesions in circumscribed regions of paracingulate cortex.

From imaging studies it is not possible to locate regions of activation in precise Brodmann areas. In terms of Talairach coordinates the activations observed in the present and previous studies cluster around the border between area 32 and area 9 in paracingulate cortex. The paracingulate (BA32) is cytoarchitectonically distinct from the anterior cingulate proper and has been described as a cingulo-frontal transition area (Devinsky *et al.,* 1995). The anterior cingulate is a large region and there have been a number of recent reviews which describe functional subdivision within it (e.g., Picard and Strick, 1996; Barch *et al.,* 2001; Bush *et al.,* 2000). The most posterior part of it (the cingulate motor area or caudal cingulate zone) is part of the motor system and, in the monkey at least, sends projections directly to spinal cord (Picard and Strick, 1996). The region of ACC immediately anterior to this (posterior rostral cingulate zone) tends to be activated in executive tasks like the Stroop (Barch *et al.,* 2001) and is sometimes referred to as a cognitive region. The most inferior regions of anterior cingulate (BA 24, 25, and 33) seem to have a role in the processing of emotion (Bush *et al.,* 2000). The region activated in the present study and in previous studies of mentalizing lies just anterior to the most anterior part of anterior cingulate proper between the putative cognitive and emotional divisions (see Fig. 2).

Previous neuroimaging studies have attributed activation in regions of anterior cingulate cortex to autonomic arousal, in particularly cognitive uncertainty and anticipatory arousal (Critchley *et al.,* 2000, 2001). It could be argued that in the present study the critical activation was due to increased anxiety experienced during the mentalizing condition. However, the region activated in those studies was significantly more posterior (Talairach coordinates, $R = 8,28,24$ and $L = -6,28,20$) to the anterior paracingulate cortex seen here ($R = 8,54,12$ and $L = -10,50,30$). Furthermore the current study was controlled so that during the scanning window the only actual difference between the two main conditions was in what the subjects believed they were doing. Thus, performance was at chance during both conditions and any anxiety generated from the resulting feedback should be the same.

It might be argued that the paracingulate activity seen here results from an emotional state evoked by the volunteer interacting with another person. In previous imaging studies of mentalizing, comparison conditions acting as nonmentalizing controls have included interactions between people (Fletcher *et al.,* 1995; Gallagher *et al.,* 2000; Brunet *et al.,* 2000; Castelli *et al.,* 2000) that have failed to activate the para-

cingulate cortex and thus in these instances social emotion has been ruled out. Furthermore the area activated in this and previous studies of mentalizing ability is anterior and superior to the region that Bush *et al.* (2000) consider to be involved in emotion.

One final argument might be that the activity observed in paracingulate cortex was a result of differences in task difficulty. Mentalizing tasks may be intrinsically more difficult and involve components typical of executive tasks. This also seems unlikely. In a meta-analysis of functional imaging studies in which cognitive demand was manipulated, Duncan and Owen (2000) found a dorsal part of the anterior cingulate cortex to be associated with increasing task difficulty. However, the coordinates of the anterior paracingulate activations seen in this and other imaging studies of mentalizing are more anterior to this region. Like-wise in the meta-analysis of ACC activations associated with Stroop-like tasks reported by Barch *et al.* (2001) the focus of activity was posterior (Talairach coordinates 3, 19, 35) to that observed in studies of mentalizing. Finally, in the current study anterior paracingulate activity was seen when mentalizing was compared with both the rule solving and baseline (random generation) conditions. Thus, if this activity were associated with performance anxiety, emotional reward, or task difficulty we would expect to see at least intermediate activity in this region in the rule solving v baseline (random selection) comparison. This was not the case.

There are, however, a number of studies that did not require volunteers to make attributions about the mental states of others that nevertheless did activate a similar region of paracingulate cortex (Frith, 2001). These studies have involved some form of self-monitoring; visual self-recognition (Kircher *et al.,* 2000), memory for autobiographical events (Maguire *et al.,* 1999, 2000), monitoring one's own speech (McGuire *et al.,* 1996a), monitoring thoughts (McGuire *et al.,* 1996b), perception of tickling (Blakemore *et al.,* 1998), perception of pain (Rainville *et al.,* 1997), and reporting emotional responses (Lane *et al.,* 1997). Taken together these results suggest that paracingulate cortex is active when we make attributions about our own mental states as well as those of other people (see Vogeley *et al.,* 2001 for a discussion of the differences between making attributions about the self and others).

On the basis of the present and previous studies we conclude that paracingulate cortex has a special role in the ability to use information to make attributions about mental states, i.e., adopting an intentional stance. There is, as yet, no computational account of the cognitive mechanism that underlies mentalizing ability and therefore we cannot assign a precise role to the paracingulate cortex. McCabe *et al.* (2001) suggest that this region acts as an active convergence zone which, during their cooperation task, "binds joint attention to mutual gains with sufficient inhibition of immediate reward gratification to allow cooperative decisions." However, this account is specific to their task and does not apply to our competitive task or to the other mentalizing tasks that have activated this region.

Leslie (1987, 1994) suggests that the mentalizing mechanism depends upon a representation of imaginary circumstances "decoupled" from reality. When explaining a person's behaviour in terms of a belief we have to recognize that this belief might not correspond to reality. Even when it conflicts with reality it is the belief not the reality that determines behavior. We also have to distinguish the representation of the reality by the other person from our representation of reality. Perhaps activity in paracingulate cortex is necessary to maintain these decoupled representations in the face of competition from representations of the actual state of the world. This function is analogous to the function of the adjacent, more posterior part of ACC. This region is active in tasks which elicit response conflict (Barch *et al.,* 2001). In the Stroop task a series of colour words (e.g., the word RED written in green ink) are presented, and the volunteer has to name the color of the ink. This less practiced response conflicts with the more usual response of reading the word. We speculate that paracingulate cortex has a similar role in handling possible conflict between actual and virtual representations, but in the more abstract domain of mental states rather than motor responses. This ability to handle different representations of the world is an essential requirement for adopting an intentional stance.

ACKNOWLEDGMENTS

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