Dissociation between Decoding and Reasoning about Mental States in Patients with Theory of Mind Reasoning Impairments

Progress Njomboro, Shoumitro Deb, and Glyn W. Humphreys

Abstract

■ Theory of mind (ToM) reasoning may involve a multiplicity of processes, including an initial stage, where cues relevant for social processes are detected and decoded, and a mentalizing stage, where the decoded information is used to reason about mental states. Here we report that the processing of lower-order facial cues relevant to social judgments can be relatively spared in patients with impaired ToM reasoning. We discuss the implications for understanding the mechanisms underlying social judgments in brain-lesioned patients. ■

INTRODUCTION

Understanding other people's mental states, commonly referred to as theory of mind (ToM), is one of the most important processes in human social cognition. Although ToM has often been treated as a unitary process, it is apparent that a range of subprocesses and precursors are involved in understanding the mental states of other people, including seeing, knowing and attending to other people, sharing attention, detecting and inferring on others' actions, recognizing affective states, and introspection (Apperly, Samson, & Humphreys, 2005; Rieffe, Terwogt, & Cowan, 2005; Abu-Akel, 2003; Stone, Baron-Cohen, Calder, Keane, & Young, 2003). One attempt to decompose ToM holds that it is based on a two-stage process (Sabbagh, 2004), requiring the involvement of both perceptual and conceptual inputs (Castelli, Happe, Frith, & Frith, 2000). It is suggested that ToM reasoning might have evolved from preexisting ''primitive'' functions that might still be influential and activated in the mentalizing process (Gallagher & Frith, 2003). These functions may include the ability to distinguish between animate and inanimate entities, the ability to share attention through following someone's gaze, and the ability to represent goal-directed actions and to distinguish between actions of the self and others (Gallagher & Frith, 2003; Frith & Frith, 1999). These functions may then be added to higher-order processes involving taking the other person's perspective (Apperly et al., 2005).

Another distinction between different processes contributing to ToM has been made by Sabbagh (2004). He suggests a separation between processes that decode other people's mental states and processes involved in reasoning about them. Decoding and reasoning may also depend on different types of information. The process of decoding other people's mental states relies on social information obtained from the environment, whereas reasoning about others' mental states requires the use of knowledge and facts (Sabbagh, 2004). Linking this argument to the distinction between preexisting and higher-order functions, we may propose that primitive processes are involved in decoding ToM, whereas higher-order functions are involved in reasoning about others' thoughts and beliefs.

One way of trying to analyze the decomposition of ToM abilities is to study cases where these abilities break down in cases of pathology. Problems in reasoning about others have been documented now in a wide range of disorders, ranging from schizophrenia and autism through to neuropsychological cases with acquired brain injuries (Bird, Castelli, Malik, Frith, & Husain, 2004; Sabbagh, 2004; Stone et al., 2003; Gregory et al., 2002; Russell et al., 2000). However, the literature on pathologies of ToM has difficulties due to individuals often suffering a range of cognitive impairments, so that their problems are not isolated to ToM reasoning. For example, although patients with frontal lobe lesions have been reported as having significant deficits in ToM (Apperly, Samson, Chiavarino, & Humphreys, 2004; Gregory et al., 2002), these patients also often have reliable problems in ancillary processes not necessarily ''core'' to ToM reasoning, such as inhibiting their own perspective (Samson, Apperly, Kathirgamanathan, & Humphreys, 2005). In other cases, patients may have significant language impairments, which may impact on their ToM abilities (although see Varley & Siegal, 2002; Varley, Siegal, & Want, 2001).

University of Birmingham, Birmingham, UK

In order to isolate processes central to ToM, Samson, Apperly, Chiavarino, and Humphreys (2004) developed nonverbal video scenarios in which a condition requiring ToM reasoning (a "false belief" condition, where an object was shifted in its location while a stooge left the room) was contrasted with a variety of control conditions where attempts were made to control for the memory load of the task. In addition, the false belief condition was designed so that the participant did not have knowledge of where a critical object was hidden, thus reducing the need for the participants to inhibit their own knowledge of where the critical object was. When these critical controls were applied, Apperly et al. (2004) and Samson et al. (2004) found that patients with lesions affecting the left temporo-parietal junction (TPJ), the superior temporal cortex (STS), and inferior parietal (IP) regions were selectively impaired in the ToM condition and unimpaired in the control conditions. In contrast, patients with frontal lobe damage failed in the control conditions in addition to the ToM case. These neuropsychological data converge with results from functional neuroimaging (Saxe & Kanwisher, 2003) in suggesting a critical role for the STS/TPJ/IP in ToM reasoning, although the exact roles for these relatively posterior brain regions remains unclear. For example, there are some grounds for arguing that these regions are critical for some of the decoding functions that may subserve ToM reasoning. For instance, several studies have shown that the STS/TPJ plays an important role in the processing of gaze and other socially meaningful cues, although these processes may be right lateralized (for a review, see Allison, Puce, & McCarthy, 2000). On the other hand, neuroimaging data have also linked activity in this region to higher-level processes involved in understanding others' intentions (Saxe, Xiao, Kovacs, Perret, & Kanwisher, 2004). Here we examine whether these posterior brain regions in the left hemisphere are necessary for processing some of the critical cues necessary for aspects of ToM reasoning, namely, the ability to judge emotional expression in faces, as well as serving ToM reasoning. Much of everyday social reasoning is based on judgments about the emotional states of others, and important cues to these states are provided by facial expressions. We ask whether individual patients who have been shown to have impairments in ToM reasoning (Apperly et al., 2004; Samson et al., 2004) also have deficits in judging facial emotions, or whether these abilities dissociate.

Judging Emotion from Faces

Recent neuropsychological evidence suggests the existence of specific neural networks responsible for decoding facial expression (Adolphs, Tranel, & Damasio, 2003; Adolphs, Damasio, & Tranel, 2002; Sprengelmeyer et al., 1997). For example, basal ganglia degeneration in early stage Huntington's disease has been shown to selectively impair the recognition of disgust and fear from facial expressions while preserving the ability to decode emotional mental states of happiness, sadness, anger, and surprise (Sprengelmeyer et al., 1997). In contrast, bilateral amygdalar damage has been linked to an impaired ability to recognize fear, anger, and disgust (Adolphs, 2002; Calder et al., 1996; Adolphs, Tranel, Damasio, & Damasio, 1995), whereas damage to the insula is thought to affect the recognition of disgust (Adolphs, 2002). These neuropsychological data are also supported by results from neuroimaging that suggest specific neural networks involved in processing emotional facial expressions (Kesler-West et al., 2000; Dolan et al., 1996).

Critical to our study is whether the STS/TPJ/IP region is also involved in processing facial emotion. Here it should be noted that the superior temporal gyrus has been implicated in decoding dynamic changeable facial expression and gaze (Adolphs, 2002), and patients with lesions overlapping this area may encounter difficulties in decoding facial emotion. Whether this is necessarily the case, and whether there is any necessary relationship between judging facial emotions and ToM abilities, is examined further in our study by testing emotion judgments in individuals who have previously been demonstrated to operate at chance level when making judgments in ToM tasks. The two patients reported, D.B. and P.F., were documented in Apperly et al. (2004) and Samson et al. (2004) as having a specific deficit in reasoning about the belief states of other people (see the Appendix for further details of these previous studies). In this study, we assess whether the patients were impaired on two facial expression recognition tests which use images derived from the Ekman and Friesen (1976) series of Pictures of Facial Affect, the Ekman 60 Faces test, and the Emotion Hexagon Test. These tests assess participants' ability to recognize the facial expressions of basic emotional states: anger, disgust, fear, happiness, sadness, and surprise. In addition, the patients were asked to give general descriptions of what it means to be in one of the above emotional states, to assess if they had conceptual knowledge about emotion even if access to that knowledge from facial stimuli might have been impaired.

METHODS

Participants

Two right-handed patients (D.B. and P.F.) were recruited for the study. Their demographic, clinical, and lesion characteristics are described in Table 1 and Figure 1. Twenty-three normal controls provided normative scores for the Hexagon experiment (mean age = 57.3 years, *SD* = 17.5) and 27 normal controls provided normative data for the Emotion Hexagon Test (mean age = 55.4 years, *SD* = 17.3). The patients continued to exhibit problems in ToM reasoning tasks at the time of the current tests, and

Table 1. Patient Characteristics and Lesion Description

Patient	*Sex/Age/Handedness*	*Main Lesion Site*	*Major Clinical Symptoms*	*Etiology*	*Years Postonset*
D.B.	M/69/R	Left inferior parietal, superior, and middle temporal gyri	Expressive aphasia	Stroke	7
P.F.	F/56/R	Left parietal extending to the superior temporal gyrus	Right extinction, dysgraphia	Stroke	9

M = male; F = female; R = right; L = left.

failed a conventional first-order story-based false belief task just prior to the current tests being administered (cf. Stone et al., 1998). P.F. had no aphasic symptoms. D.B. had an expressive aphasia, with some pronounced word-finding difficulties. For example, on the picture-naming task from the BORB (Riddoch & Humphreys, 1993), D.B. named 35/76 items correctly, showing a clear impairment. However, he performed at a control level on the Associative Match test (28/30), indicating relatively intact semantic knowledge about objects.

Materials and Procedures

The tests were run on a computer from the *Facial Expression of Emotion—Stimuli and Tests* (FEEST) CD-ROM. At the start of each test session, participants were asked to give an explanation of what it means to experience each of the six emotions, and give examples of scenarios under which the emotions could be experienced. This was done to make sure participants knew about the six basic emotional mental states assessed in the study. The participants read test instructions that appeared on the computer screen before the test. One face at a time was presented for 5 sec onto the computer screen and this was followed by a blank screen. The participants had to decide which of the emotions (anger, disgust, fear, happiness, sadness, and surprise) best described the facial expression shown. The emotion categories were presented as tabs at the base of the computer screen and remained visible throughout the test. Participants had to click using a mouse at the emotion label tab they thought matched the facial expression and could take as long as they wanted to make a response. The next face was not presented until a response was made. Responses were automatically recorded and scored onto an Excel-compatible spreadsheet file.

The Ekman 60 Test

The faces that make up the Ekman 60 stimuli were derived from the Ekman and Friesen (1976) series of facial expressions images showing the six emotional states of anger, disgust, fear, happiness, sadness, and surprise. The stimuli images are shown in Figure 2. There was a practice session made up of six facial expressions, one on each of the six emotions and faces making these practice trials are shown on the extreme left of Figure 2.

The Emotion Hexagon Test

The morphed faces used in the test are shown in Figure 3. The faces on the Emotion Hexagon Test are computer-manipulated such that each emotions is presented in graded levels of difficulty, hence, more difficult to recognize. Each emotion is mixed or blended with another which it is most likely confused with,

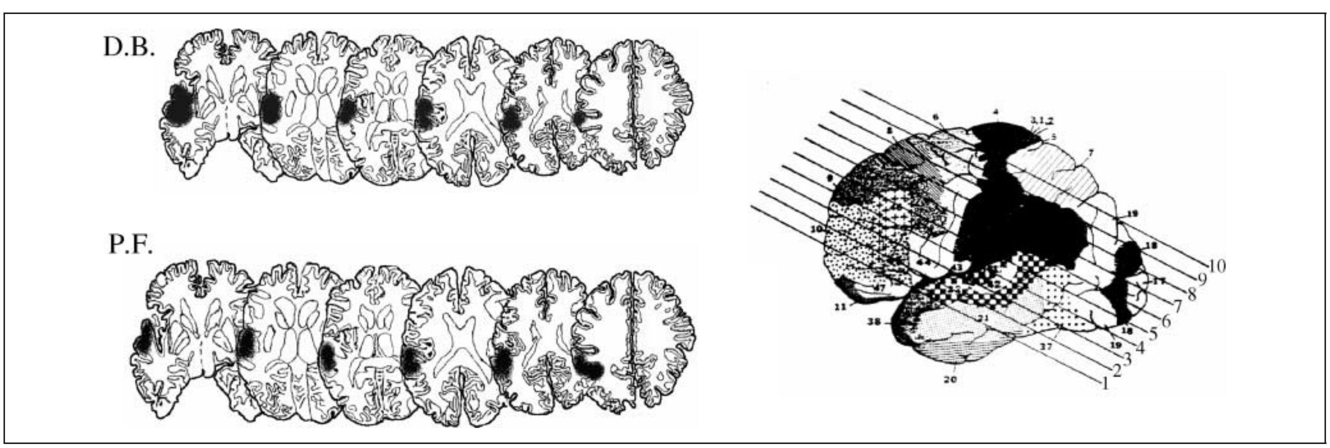

Figure 1. Lesion reconstructions of the patients drawn from standard slices in Gado, Hanaway, and Frank (1979). The figure on the right shows the 10 slices used, although only Slices 3 to 8 are depicted. The left of each slice represents the left hemisphere.

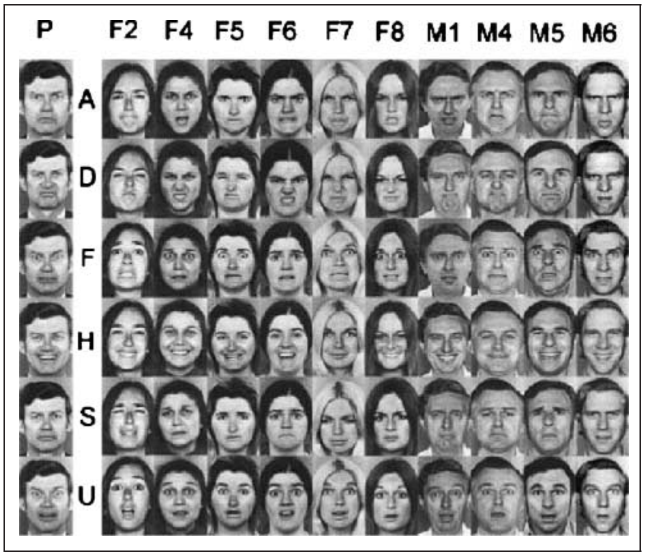

Figure 2. Photographs of facial expressions used in the Ekman 60 Faces Test. The extreme left column shows practice (P) stimuli. Rows show facial expressions of anger (A), disgust (D), fear (F), happiness (H), sadness (S), and surprise (U) (Young et al., 2002).

resulting in the following sequence; happiness–surprise–fear–sadness–disgust–anger. (See Young, Perret, Calder, Sprengelmeyer, & Ekman, 2002, for a detailed description of how the Emotion Hexagon Test stimulus was made.) The ends of this sequence (anger and happiness) join to form the emotion hexagon shown in Figure 4.

A total of 120 trials split into 4 blocks were administered to each participant. A practice block of 30 trials (practice trials data was not put for analysis) was followed by 120 trials split into 5 blocks made up of 30 trials each. Each block was made up of a randomized single presentation of each of the 30 faces in Figure 4. Responses were made by using a mouse to click on one of the six emotion words (anger, disgust, happiness, sadness, surprise, and happiness) presented at the bottom of the screen and the software recorded responses on an Excel-compatible spreadsheet file.

RESULTS

Descriptions of Emotions

D.B. and P.F. gave reasonable answers when asked what it means to say someone is angry, disgusted, afraid, happy, sad, or surprised. The patients were also able to give reasonable examples of scenarios under which people can experience these emotions, for example, describing happiness in the context of winning a prize and sadness in the context of the death of a friend.

The Ekman 60 Faces Test

The Ekman 60 Faces Test consists of 10 facial expression images for each of the six emotions, resulting in a total score of 60. D.B. and P.F.'s overall scores across all six basic emotions taken together were within the normal range (controls' mean total number of correct responses = 49.9/60, SD = 3.9; D.B. = 47/60, Z = 0.72, $p > .05$; P.F. = 48/60, Z = 0.46, $p > .05$). Therefore, D.B. and P.F. showed normal performance on this test. Both patients performed at ceiling when asked to judge happiness (10/10). For the other emotion categories, D.B. and P.F. scored within the normal range: anger (controls' mean correct responses = 7.8/10, SD = 1.5; D.B. = 9/10, Z = 0.8, $p > .05$; P.F. = 8/10, Z = 0.13, $p > .05$), disgust (controls' mean correct responses = 8.4/10, SD = 1.5; D.B. = 8/10, Z = 0.27, $p > .05$; P.F. = 7/10, Z = 0.93, $p > .05$), fear (controls' mean correct responses = 7/10, SD = 2.4; D.B. = 5/10, Z = 0.83, $p > .05$; P.F. = 6/10, Z = 0.42, $p > .05$), sadness (controls' mean correct responses = 8/10, SD = 1.6; D.B. = 7/10, Z = 0.62, $p > .05$; P.F. = 7/10, Z = 0.62, $p > .05$), and surprise (controls' mean correct responses = 8.6/10, SD = 1.4; D.B. = 8/10, Z = 0.43, $p > .05$; P.F. = 10/10, Z = 1, $p > .05$). These results are shown in Table 2 below.

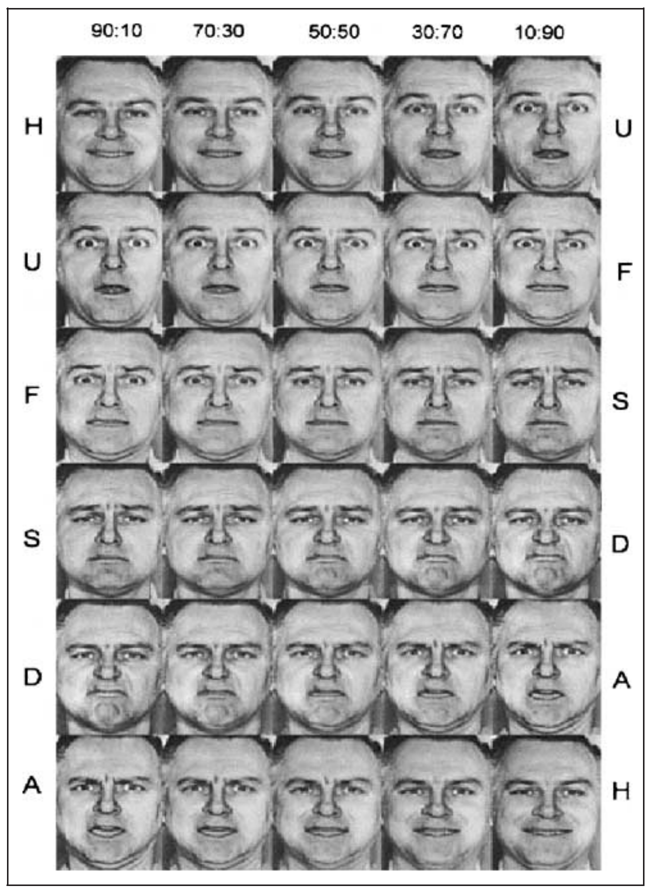

Figure 3. Stimuli used in the Emotion Hexagon Test. From left to right, the columns show 90%, 70%, 50%, 30%, and 10% morphs along each continuum. From top to bottom, the continua shown in each row are happiness (H)–surprise (U), surprise (U)–fear (F), fear (F)–sadness (S), sadness (S)–disgust (D), disgust (D)–anger (A), anger (A)–happiness (H) (Young et al., 2002).

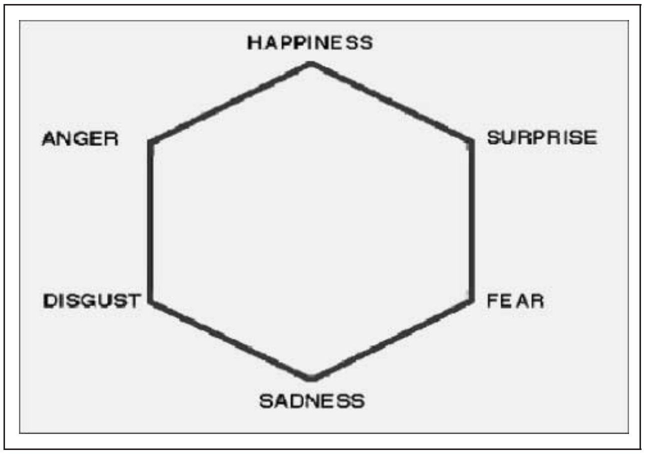

Figure 4. The emotion hexagon. The hexagonal presentation illustrates how images were blended to come out with stimuli for the hexagon test used for this study. Happiness was blended with surprise, surprise with fear, fear with sadness, sadness with disgust, disgust with anger, and anger with happiness in proportions of 90:10, 70:30, 50:50, 30:70, and 10:90 (Young et al., 2002).

The Emotion Hexagon Test

Results from the Emotion Hexagon Test can be converted to a score out of a maximum of 120 for the recognition of all the six emotions, or scores out of 20 for the recognition of each basic emotion.

D.B. and P.F.'s overall score of 100/120 each across the six emotion categories was within the normal range (controls' mean response = 109; *SD* = 7; D.B. and P.F. = 100/120 each, $Z = 1.28$, $p > .05$).

Both patients had normal scores on judgments of happiness (control = 19.7/20, *SD* = 0.9; D.B. = 20/20, $Z = 0.33$, $p > .05$; P.F. = 20/20, $Z = 0.33$, $p > .05$), fear (control's mean score = 17.8, *SD* = 6; D.B. = 16/20, $Z = 0.3$, $p > .05$; P.F. = 11/20, $Z = 1.13$, $p > .05$), disgust (control's mean score = 17.4/20, *SD* = 3.9; D.B. = 18/20, $Z = 0.15$, $p > .05$; P.F. = 18/20, $Z = 0.15$, $p > .05$), and surprise (controls' mean score = 17/20, *SD* = 3.7; D.B. = 18/20, $Z = 0.27$, $p > .05$; P.F. = 19/20, $Z = 0.54$, $p > .05$). However, only P.F. scored within the normal range for judgments of anger (controls' mean score = 17.7, *SD* = 2.3; P.F. = 15/20, $Z = 1.17$, $p > .05$; D.B. = 13/20). Both D.B. and P.F. obtained significantly lower scores for the category of sadness (controls' mean score = 19.6, *SD* = 0.8; D.B. = 15/20, $Z = 5.75$, $p < .001$; P.F. = 17/20, $Z = 3.25$, $p < .001$). Table 3 gives the means and standard deviations for the control sample as well as standard scores for the two patients.

DISCUSSION

D.B. and P.F. showed overall normal levels of performance on judging facial emotions in the Ekman 60 Faces task and the Emotional Hexagon task. They were also able to demonstrate a conceptual understanding of the six emotion categories. The fact that D.B. and P.F. could perform within the normal range overall on the relatively difficult hexagon test indicates that the left STS/TPJ/IP region has very limited, if any, influence on the decoding of emotional mental states from facial expressions, and that a deficit in ToM reasoning can coexist with a relatively preserved ability to decode facial emotions. The only emotion both patients had any difficulty with was with sadness, and this was only in the hexagon task; there was no evidence for an across-the-board deficit. We believe this is the first time that a dissociation has been reported between spared decoding of facial emotions and impaired ToM reasoning. This, in turn, implies that the belief reasoning deficits shown by D.B. and P.F. are not a product of deficits in low-level processing of mental state reasoning cues concerning facial emotions, at least. The study thus raises the possibility that the decoding and recognition of mental states relies on neural pathways and brain areas that are distinct from regions supporting reasoning about these mental states.

Table 2. Controls' Mean Scores and Patients' Individual Scores on the Ekman 60 Test

	Total	*Anger*	*Disgust*	*Fear*	*Happiness*	*Sadness*	*Surprise*
Mean Scores for Normal Controls (n = 27)							
Mean	49.8	7.8	8.4	7	10	8	8.6
SD	3.9	1.5	1.5	2.4	0	1.6	1.4
Patients' Scores and Z Scores							
D.B.	47	9	8	5	10	7	8
	$Z = 0.72$	$Z = 0.8$	$Z = -0.27$	$Z = -0.83$	$Z =$ nan	$Z = -0.63$	$Z = -0.43$
P.F.	48	8	7	6	10	7	10
	$Z = -0.46$	$Z = 0.13$	$Z = -0.93$	$Z = -0.42$	$Z =$ nan	$Z = -0.63$	$Z = 1.0$

Table 3. Mean Scores for Controls and Patients' Individual Scores on the Hexagon Test

	Total	*Anger*	*Disgust*	*Fear*	*Happiness*	*Sadness*	*Surprise*
Scores for Normal Controls (n = 23; mean age = 57.3, SD = 17.5)							
Mean	109	17.7	17.4	17.8	19.7	19.6	17
SD	7	2.3	3.9	6	0.9	0.8	3.7
Patients' Scores							
D.B.	100	13*	18	16	20	15**	18
	$Z = -1.29$	$Z = -2.04$	$Z = 0.15$	$Z = -0.3$	$Z = 0.33$	$Z = -5.75$	$Z = 0.27$
P.F.	100	15	18	11	20	17**	19
	$Z = -1.29$	$Z = -1.17$	$Z = 0.15$	$Z = -1.13$	$Z = 0.33$	$Z = -3.25$	$Z = 0.54$

*Scores are significantly below the control mean: $Z > 1.65$, $p < .05$.

**Scores are significantly below the control mean: $Z > 2.33$, $p < .01$.

Some recent studies using event-related potentials have also concluded that the decoding and mentalizing components of ToM processing are associated with distinct, nonoverlapping neural systems (Sabbagh, Moulson, & Harkness, 2004). Sabbagh and his colleagues' event-related potential study suggested the involvement of inferior frontal and anterior temporal regions of the right hemisphere in mental state decoding and the involvement of left prefrontal areas in mental state reasoning. The current study, alongside the ToM studies of Apperly et al. (2004) and Samson et al. (2004), extend this by suggesting that the left STS/TPJ/IP region is necessary for ToM reasoning, but not for decoding cues that may support mental state reasoning. Exactly which brain areas are critical requires further study, however, given that some patients with damage to apparently overlapping structures to the current cases can show good ToM reasoning (e.g., Patient P.H.; Apperly et al., 2004; Varley et al., 2001).

It is possible that different brain areas or pathways are involved at different stages of ToM processing. One possibility is that left STS/TPJ/IP regions are responsible for higher-order mentalizing processes that are required for belief reasoning, but not for decoding facial emotions. Alternatively, it may be that ToM reasoning depends upon decoding processes additional to those required when judging facial emotion, and these additional decoding processes may be compromised in the patients. As we have noted, there is research suggesting the STS/TPJ is involved in the processing of precursors of ToM from the social environment, including gaze direction and eye movements, and that these precursors allow humans to formulate knowledge of what others are perceiving and to view the world from their perspective (Frith & Frith, 2006). Although the ability to judge facial emotion is dependent on cues about eye position, there is also good evidence that facial emotions are conveyed by more global, configural cues from faces (see Baudouin & Humphreys, 2006; Calder & Jansen, 2005; Calder, Young, Keane, & Dean, 2000). Thus, it may be that the present patients were able to respond to configural cues modulated by intact brain regions that seem sensitive to facial configurations (e.g., the right fusiform gyrus; see Yovel & Kanwisher, 2005), whereas there may remain a specific deficit in using subtle information about eye gaze (perhaps along with other nonverbal cues) as a "scaffold" to support ToM reasoning. These questions necessitate further research. Nevertheless, the present results do indicate that the processing of emotional mental states may occur in dedicated and distinct specialized pathways that are separable from pathways that process other forms of mental states such as beliefs. A dedicated emotional mental state processing system would make evolutionary sense considering how heavily reliant human social interaction is on emotional states communicated through facial expression.

The dissociation between ability to decode emotional mental states from faces versus the ability to reason about mental states in ToM tasks is particularly important because most patient groups with a ToM impairment (e.g., schizophrenic and autistic patients) also present with deficits in the recognition and decoding of emotional facial emotions (Blair, 2003; Mandal, Pandey, & Prasad, 1998, Gaebel & Wolwer, 1992). Isolating components of ToM reasoning, especially through associations and dissociations observed in adults with an acquired brain damage, allows us to gain more insight into the cognitive structures that support this process and shed light on ToM impairments in adult clinical populations. This may also help us gain some evidence in the long-standing debate on whether ToM reasoning is a domain-specific or domain-general process as well as explain the nature of the involvement of the different areas activated in imaging studies on ToM.

Static facial expression displays were used in this study. Future studies may consider extending the research to also include dynamic displays. We, however, cannot think of any strong reason why, for instance, our patients would fail to decode emotional mental states from dynamic displays of facial expressions. There is robust evidence that dynamic displays of facial expressions actually enhance recognition of the emotional content of the expressions (e.g., Harwood, Hall, & Shinkfield, 1999). Imaging studies on normal participants have also shown comparatively higher brain activations associated with dynamic compared to static displays of facial expressions (e.g., Sato, Kochiyama, Yoshikawa, Naito, & Matsumura, 2004). There is, however, some suggestions that different neural networks may underlie the decoding of social information from static versus dynamic face displays (e.g., Kilts, Egan, Gideon, Ely, & Hoffman, 2003).

APPENDIX

Samson et al.'s (2004) belief reasoning tasks address some of the major concerns with tasks aimed at assessing belief reasoning especially in patients with an acquired brain damage. These relate to the likely confounding on performance from other unprecedented deficits in domains such as semantic processing, executive deployment, and memory. In their video-based, reality-unknown, nonverbal false belief task, a man placed an object in one of two identical boxes in full view of another female actor but without the participant seeing which box the object was placed in (participants did not know the reality about which box the object had been put). The woman then left the room, and while away, the male actor swapped the two boxes. Upon returning, the woman then pointed at one of the boxes. Locating the box containing the object then required participants to infer on the woman's false belief about the two boxes (realizing that the woman's belief about the location of the object is no longer true because the boxes where swapped in her absence) and to realize that the object was, therefore, in the box other than the one the woman pointed at. Participants did not know about the location of the objects until they inferred on the woman's false belief. This ensured participants' attribution of false belief could not be disrupted by their own knowledge of the correct answer, which is a likely effect especially in brain-damaged patients with executive deficits. Other trials controlled for memory and inhibition effects (see Samson et al., 2004, for a full description of the tasks). In Samson et al.'s study, the present patients (D.B. and P.F.) failed to perform above-chance level (one tailed p value associated with a score of 10/12 correct = .019) on the false belief trials in this video-based nonverbal task (all the patients achieved scores below 9 out of a total of 12 trials), but did not make errors on the memory and inhibition control trials (all patients performed all 12 trials correctly, on both the inhibition and memory control trials). The patients also failed on a story-based belief-reasoning task, although D.B. also made errors on control trials that could be attributable to problems in semantic processing due to his aphasic state.

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Reprint requests should be sent to Progress Njomboro, University of Birmingham, Department of Psychiatry, Division of Neuroscience, Queen Elizabeth Psychiatric Hospital, Mindelsohn Way, Birmingham B15 2QZ, UK, or via e-mail: P.Njomboro@gmail.com.

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