**Seeing it my way:**

**A case of a selective deficit in inhibiting self-perspective**

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**Summary**

Little is known about the functional and neural architecture of social reasoning, one major obstacle being that we crucially lack the relevant tools to test potentially different social reasoning components. In the case of belief reasoning, previous studies tried to separate the processes involved in belief reasoning *per se* from those involved in the processing of the high incidental demands such as the working memory demands of typical belief tasks (e.g., Stone *et al.*, 1998; Samson *et al.*, 2004). In this study, we developed new belief tasks in order to disentangle, for the first time, two perspective taking components involved in belief reasoning: (1) the ability to inhibit one's own perspective (self-perspective inhibition) and (2) the ability to infer someone else's perspective as such (other-perspective taking). The two tasks had similar demands in other-perspective taking as they both required the participant to infer that a character has a false belief about an object's location. However, the tasks varied in the self-perspective inhibition demands. In the task with the lowest self-perspective inhibition demands, at the time the participant had to infer the character's false belief, he or she had no idea what the new object's location was. In contrast, in the task with the highest self-perspective inhibition demands, at the time the participant had to infer the character's false belief, he or she knew where the object was actually located (and this knowledge had thus to be inhibited). The two tasks were presented to a stroke patient, WBA, with right prefrontal and temporal damage. WBA performed well in the low-inhibition false belief task but showed striking difficulty in the task placing high self-perspective inhibition demands, showing a selective deficit in inhibiting self-perspective. WBA also made egocentric errors in other social and visual perspective taking tasks, indicating a difficulty with belief attribution extending to the attribution of emotions, desires and visual experiences to other people. The case of WBA, together with the recent report of three patients impaired in belief reasoning even when self-perspective inhibition demands were reduced (Samson *et al.*, 2004), provide the first neuropsychological evidence that (a) the inhibition of one's own point of view and (b) the ability to infer someone else' s point of view, rely on distinct neural and functional processes.

Key words: frontal lobe; theory of mind; self perspective; false belief

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## Introduction

In the past decade, there has been increasing evidence showing that two main brain regions, the prefrontal cortex and the temporo-parietal junction, are involved when we reason about mental states such as beliefs, desires or emotions (an ability often referred to as having a "theory of mind"). Neuroimaging studies of theory of mind consistently show activation of the prefrontal lobe when healthy adults reason about other people's mental states (Fletcher *et al.*, 1995; Castelli *et al.*, 2000; Gallagher *et al.*, 2000; Vogeley *et al.*, 2001; Ruby and Decety, 2003; Iacoboni *et al.*, 2004). Several neuropsychological studies have also shown that prefrontal lesions can disrupt the patient's ability to reason about other people's mental states (Stone *et al.*, 1998; Rowe *et al.*, 2001; Goel *et al.*, 2004; but for evidence against the necessary role of the prefrontal lobe see Bird *et al.*, 2004). More recently, some studies have shown the additional crucial contribution of the temporo-parietal junction in theory of mind, by highlighting it's specific activation in healthy adults (Saxe and Kanwisher, 2003) and it's necessary role in brain-damaged patients (Samson *et al.*, 2004) when participants reason about someone else's mental states. To date, however, the relative functional contribution of the prefrontal areas *versus* the temporo-parietal areas remains unclear.

It has been suggested that the temporo-parietal junction plays a role in relatively low-level social cognition since this region seems to be involved in the processing of socially meaningful visual cues such as gaze direction and goal-directed action (for a review see Frith and Frith, 1999; Allison *et al.*, 2000). However, recent evidence suggests that the temporo-parietal region could also be involved in higher-level social cognition, including social reasoning. Saxe and Kanwisher (2003), for example, found that a region within the temporo-parietal junction was significantly more activated when healthy adults reason about mental states compared with when they processed a person's appearance (controlling for more low-level social cognition) or reasoned about non-social events. Moreover, Samson *et al.* (2004) reported the case of three patients with damage to the temporo-parietal junction whose mental state reasoning deficit could not be attributed solely to difficulties in processing socially meaningful visual cues. However, the precise role of the temporo-parietal junction remains unclear.

Most widely accepted is the notion that the frontal lobes support the ability to have a theory of mind. At least three different forms of frontal contribution can be highlighted. Firstly, given the well-known frontal lobe involvement in executive control (e.g., Stuss and Benson, 1986; Duncan and Owen, 2000), it is plausible that the frontal lobe contribution to theory of mind is with the control processes that support complex reasoning. In classic theory of mind tasks, participants usually need to integrate complex narratives and remember sequences of events on the basis of which the action of a character has to be predicted or explained. Frontal lobe involvement may be necessary to handle these high incidental task demands. Consistent with this hypothesis, some patients with frontal lesions make errors both on mental state reasoning items and on control stimuli which do not require reasoning about mental states but which are closely matched to the mental state items on incidental task demands (e.g. Apperly *et al.*, in press). Moreover, when provided with external aids that alleviate the working memory load, the ability to reason about mental states can improve in some frontal patients (e.g. Stone *et al.*, 1998). Nevertheless, the possibility that frontal regions also have a more specific role in social cognition is left open by neuroimaging data suggesting that frontal regions associated with executive control need not overlap with those specifically associated with mental state reasoning (Gallagher and Frith, 2003).

Reasoning about beliefs, desires, knowledge and the like necessarily involves the ability to adopt perspectives or points of view other than one’s own. Some authors have proposed a second type of frontal lobe contribution to theory of mind: the frontal lobes could be involved in holding simultaneously and “decoupling” the self- and other-perspectives, a role which may not reduce to more basic executive functions such as working memory or inhibitory control (Gallagher and Frith, 2003). Evidence in favour of this hypothesis comes from neuroimaging studies showing that the medial frontal regions near the anterior cingulate cortex are activated when participants interact in competitive or reciprocity games with a computer, but only when they think that another participant commands the computer and not when they think that the computer generates rule-based strategies (Gallagher *et al.*, 2002; McCabe *et al.*, 2001). Thus, whereas the actual game is identical in both conditions, in one condition the participants take into account another person’s perspective whereas in the other condition, no such perspective taking is involved.

Other authors have put forward a third possible contribution of the frontal lobes in theory of mind and have argued that the frontal lobes would play a crucial role in *inhibiting* one's own perspective when reasoning from someone else's discrepant perspective (Ruby and Decety, 2003; Ruby and Decety, 2004). This latter hypothesis stems from the observation that young children, before fully developing a theory of mind and when asked to infer someone else's mental state, usually respond according to their own, more salient, mental state (e.g., Moore *et al.*, 1995). Such "egocentric errors" have also been observed, under some circumstances, in healthy adults (Mitchell *et al.*, 1996; Keysar *et al.*, 2003; e.g., Bernstein *et al.*, 2004). These errors have often been noted in the case of epistemic mental states (beliefs and knowledge rather than desires and emotions, see e.g., Leslie & Thaiss, 1992; Russell et al, 1991), and have sometimes been referred to as reflecting a "reality bias" (Mitchell and Lacohee, 1991; Saltmarsh *et al.*, 1995), "epistemic egocentrism" (Royzman *et al.*, 2003) or the "curse of knowledge" (Birch and Bloom, 2004). A number of neuroimaging studies have looked at brain activation when participants adopt someone else's perspective as compared to when they adopt their own (self) perspective, in the case of conceptual, emotional or visual perspective taking or in the case of experiencing agency (Vogeley *et al.*, 2001; Farrer and Frith, 2002; Ruby and Decety, 2003; Grezes *et al.*, 2004; Ruby and Decety, 2004; Seger *et al.*, 2004; Vogeley *et al.*, 2004). This comparison usually shows extensive fronto-parietal activation, sometimes extending into the temporal lobe. However such a contrast reflects not only the inhibition of self- perspective but also the inference of the other person's perspective *per se*. To our knowledge, only one study has tried to disentangle these two processes (although this was not the authors' explicit intention): namely, on the one hand, the inhibition of one's own perspective when inferring someone else's perspective and, on the other, the inference of someone else's perspective (Vogeley *et al.*, 2001). This study revealed that a single region located in the right inferior frontal gyrus was activated when participants attributed a mental state to a character in a story in which the participants themselves also featured (high self-perspective), compared to a condition in which they attributed a mental state to a character in a story in which the participants did not feature (low self-perspective). This contrast permits the isolation of inhibition of one's own perspective. To date, no neuropsychological study has confirmed the necessary role of this region for the inhibition of self-perspective. However, recent neuropsychological evidence shows that the right inferior frontal gyrus has a necessary role in response inhibition in non-social tasks (Aron *et al.*, 2003; Aron *et al.*, 2004a). In addition, there are some observations showing that lesions to the adjacent right frontopolar gyrus can produce egocentric errors in social reasoning (Anderson *et al.*, 1999) – though this latter study did not contrast directly the ability to inhibit one's own perspective and the ability to infer someone else's perspective.

From the above review, it seems possible that different areas both within the frontal lobes and within the temporo-parietal junction have contrasting functional contributions to theory of mind. One obstacle to specifying these contributions is that neuroscientists lack the relevant tools to test potentially different components within theory of mind tasks. For example, disentangling the inhibition of one's own perspective from the inference of someone else's perspective raises a major empirical problem. Consider a commonly used theory of mind task that requires the participants to reason about the "false" beliefs of another person (e.g., Wimmer and Perner, 1983). The participants hear a story in which Billy puts his chocolate in the cupboard then goes outside to play. While Billy is outside, his mother moves the chocolate to the refrigerator. In the crucial test question, the participants are either asked where Billy thinks his chocolate is located, or they are asked to predict where Billy will look for his chocolate when he returns to the house. This task generates a discrepancy between one's own (self-) perspective and the perspective of the character (the 'other'-perspective). When the participants respond correctly, we can be sure they are answering from Billy's perspective and not their own. However, in this task, not only must participants infer that Billy has a different perspective (in this case, a false belief), but they must also attribute belief *content* that directly conflicts with what they know themselves to be true (Billy thinks the chocolate is in the cupboard, but in fact the participants know it is in the refrigerator). It may be that these aspects of the task are both part of the same perspective taking process, or it could be that they are distinct components. This question cannot be addressed with methods in which these two aspects always co-occur.

In our previous studies (Samson *et al.*, 2004; Apperly *et al.*, in press), we used a false belief task, adapted from Call and Tomasello (1999), where the participant lacks knowledge that could conflict with the false belief they must attribute. Importantly our tasks were based on non-verbal videos and were designed to eliminate or control for incidental processing demands. This makes them particularly suitable for neuropsychological studies of whether the frontal lobes have any role in theory of mind beyond the need to handle high processing demands. The participant's task is to work out which of two boxes contains a hidden object. A woman in the video sees inside the boxes. On false belief trials, the woman leaves the room and in her absence, the locations of the two boxes are swapped. The woman returns to the room and offers the participant a clue about the location of the object by indicating one of the two boxes. This clue will be wrong, but is useful, provided the woman's false belief is taken into account. This task generates a discrepant perspective between the participant and the woman in the same way as in more standard false belief tasks. However, because the woman's false belief is the basis on which the participant infers reality (the participant doesn't know in which box the object is located before the woman points to the wrong box), there is no possibility of this knowledge of reality interfering with the initial process of realising that the woman has a conflicting perspective. Thus, although the task does not eliminate all possible self-perspective inhibition demands (because the task still entails discrepant self- and other-perspectives), it at least eliminates one demand on self-perspective inhibition linked to the discrepant belief content. For simplicity, we will refer to this task as the "low inhibition" false belief task, although we remain agnostic about whether this condition makes lower demands on inhibitory processes when compared with more standard tasks, or whether it actually eliminates one kind of inhibitory demand.

For comparison with the low inhibition false belief task we designed a new task, closely matched in terms of incidental task demands but in which the discrepancy between self and other belief content is reintroduced. We used similar videos to before (Samson *et al.*, 2004; Apperly *et al.*, in press), but this time, at the point when the participant has to infer the character's false belief, the participant knew the new location of the object. Thus, as in classic false belief tasks, this new task entails both a discrepancy of perspective (the woman in the video did not see the boxes being swapped, so will have a false belief) and discrepant belief content (e.g., the woman thinks the object is in the box on the left; the participant knows the object is in the box on the right). We refer to this as the "high inhibition" false belief task.

In this paper, we report the data from WBA, a stroke patient who was presented with the high and low inhibition versions of the false belief task (WBA's performance in the "low inhibition" false belief task has been reported in Apperly *et al.*, in press. Note that in that paper, WBA was also presented with a verbal false belief task that placed high self-perspective inhibition demands. However due to the higher incidental task demands of this verbal task, WBA made several errors on the control trials so that his belief reasoning performance in that task could not be reliably interpreted). WBA's lesion overlapped the region highlighted by Vogeley *et al.* (2001) as possibly sustaining the ability to inhibit one's own perspective. If WBA's brain lesion affected a region that is necessary for self-perspective inhibition, we would expect WBA to make more errors in the "high inhibition" false belief task compared to the "low inhibition" false belief task, since this latter task is less demanding in terms of self-perspective inhibition. Such a pattern would contrast with our prior data where lesions of the temporo-parietal junction were associated with a selective problem in theory of mind tasks with low self-perspective inhibition demands (Samson *et al.*, 2004; Apperly *et al.*, in press). Such contrasting patterns across the two false belief tasks would allow us to distinguish the process of taking someone else's perspective (impaired in the patients with temporo-parietal junction lesions, but spared in WBA) from the process of self-perspective inhibition (impaired in WBA). We also presented WBA with two additional perspective taking tasks in order to assess whether his profile in belief reasoning would generalise across different mental state processing tasks (i.e. inferring emotions, desires and visual experiences). We discuss the implications of our findings for current models of theory of mind.

**Case report**

WBA is a right-handed man with a degree in law, who, in 2001 at the age of 56, suffered a right hemisphere stroke. The MRI performed 8 months post-onset showed a lesion to the right inferior and middle frontal gyri extending into the right superior temporal gyrus (see Figure 1). Strikingly, WBA's lesion completely overlapped (although also extending) the foci of activation highlighted by Vogeley *et al.* (2001) when contrasting the inference of someone else's mental state with high *versus* low demands on inhibition of one's own perspective.

WBA's stroke produced a left-side weakness and cognitive deficits. The general neuropsychological assessment performed in 2002 and early 2003 showed difficulties in learning new verbal information in long-term memory, working memory problems, selective and sustained attention difficulties as well as an executive control deficit, especially in inhibition, shifting and rule detection. WBA also showed some language problems, mainly characterised by nonfluent speech, difficulties in using deictic words (e.g. I, you, today etc.) and difficulties in sentence construction and sentence comprehension (see Table 1 for more details). A further assessment performed in 2004 showed a striking improvement in verbal long-term memory, selective attention and some aspects of working memory. Inhibition abilities remained poor however, and, although his speech improved globally, it was still characterised by the same features. The patient himself complained about his language expression difficulties and his lack of flexibility.

WBA's theory of mind abilities were tested between 2003 and 2004, at a time at which he had returned to his professional activities and was fully independent at home.

**Experiment 1: Attributing beliefs to someone else**

*Method*

*Test 1 – Low inhibition false belief task.* WBA was presented with a false belief task consisting of short nonverbal videos. For each video, WBA was asked to find in which of two boxes a green object was located. WBA was told that the woman in the video would help him find where the green object was. The false belief scenario showed the woman watching as a man placed the green object in one of two boxes; however, crucially, the camera did not show which box the green object was placed in. The woman then left the room and while she was away, the man swapped the boxes. When the woman returned, she pointed to one of the boxes. In order to find out in which box the green object was located in, WBA had to infer that the woman had a false belief (i.e. she thinks the object is in the old location) and therefore WBA had to point to the opposite box to the one the woman pointed to. Importantly, in the task, the participant had no idea where the green object was located before he inferred that the woman had a false belief. Crucially therefore, the inference concerning someone else's belief did not require inhibition of one's own knowledge of the correct answer. In the task, 12 false belief scenarios were mixed with 12 memory control and 12 inhibition control scenarios, i.e. scenarios placing similar incidental processing demands (e.g. working memory demands) but for which the correct answer did not require inferences about the woman's belief (see supplementary method for more details). Twenty-four filler-trials were also added to minimise the possibility that the false belief trials could be solved by superficial means (e.g. always responding to the box opposite from where the woman pointed). All 72 trials were presented in 4 different blocks, each block being presented in a separate session.

*Test 2 – High inhibition false belief task.* The high inhibition false belief task consisted of similar nonverbal videos to those in the low inhibition task. This time, WBA was asked to indicate which of the two boxes the woman in the video would open first in order to find the green object. In the false belief scenario, the woman watched as the man placed the green object in one of the two boxes. The woman then left the room and, while she was outside, the man moved the green object from one box to the other in full view of the participant (ensuring that the participant knew the object's new location). Crucially, and in contrast to the low inhibition task, in order to find out which box the woman would open first, WBA had not only to infer that the woman has a false belief (i.e. she thinks that the object is in the old location) but he also had to inhibit his own knowledge of  the object's new location. The 12 false belief trials were mixed with 12 memory control as well 24 anti-strategy filler trials (see supplementary method for more details). All 48 trials were presented in 3 different blocks, each block being presented in a separate session.

*Results*

*Test 1 – Low inhibition false belief task.* WBA scored 11/12 on the false belief trials as well as 10/12 and 12/12 for the memory and inhibition control trials, respectively (see Figure 2)[1]. All three scores were significantly above chance level. Importantly, WBA made no errors on the anti-strategy trials, indicating that his success on the false belief trials did not result from the use of a superficial strategy for solving the task.

*Test 2 – High inhibition false belief task.* WBA scored 1/12 on the false belief trials, a score significantly below chance level (one-tailed *P*-value associated with getting 1/12 correct=0.003). This indicates that he was not guessing but, rather, he was systematically predicting the woman's behaviour on the basis of his own knowledge of the reality rather than on the basis of her (false) belief. WBA's good score (12/12) on the memory control trials also indicated that his poor score on the belief trials was not due to difficulties in handling the incidental task demands. Moreover, two other brain-damaged patients (reported in Apperly *et al.*, in press) performed similarly on the same two tasks, indicating that WBA's poor score on the high inhibition version of the false belief task did not simply result from the task being more difficult to perform.

[1] WBA's overall score in Test 1 has been previously published as part of a group study (Apperly *et al.*, in press)

As in Test 1, feedback showing the correct response was given at the end of each video (irrespective of the accuracy of the participant's response), however this had no effect on WBA's performance. On several occasions, WBA overtly reported that he realised that he was always failing when the woman in the video was outside the room and the boxes were swapped. Yet, he could not identify why he was unable to find the correct answer in that case. Interestingly, the same cues (the woman being outside and the boxes being swapped) were sufficient for WBA to solve the false belief trials in the "low inhibition" false belief task (Test 1). This could suggest a serial process with the inhibition of one's own perspective being a preliminary and necessary step before someone else's perspective can be inferred. Here, damage to the process of self-perspective inhibition (under conditions of high inhibition requirements) prevented WBA from using an intact ability to infer someone else's view.

**Experiment 2: Attributing visual experiences, desires and emotions to someone else**

*Method*

*Test 3 – Visual perspective taking.* In order to assess WBA's ability to infer someone else' visual experience, we adapted an existing task from the literature (Langdon and Coltheart, 2001). WBA sat at a table with one person at each side of the table (WBA being on one side, two examiners - Uma and Dana – and a pretend-third person symbolised by a picture –Peter – on the other side). Four coloured circles (red, yellow, blue and green) were placed in the centre of the table to form a square. On each trial WBA was asked how someone (himself, Uma, Dana or Peter) around the table would see the circle display. To answer, WBA had to point to one visual representation of the 4 circles among a three choice response. One of the choice responses always conformed to WBA's perspective, another choice response always conformed to someone else's perspective and a third response conformed to a slight alteration (e.g. two position inversions) of another person's perspective. The position of the circles was changed from trial to trial. The task consisted of 40 trials (10 per perspective) presented in random order.

*Test 4 – Social perspective taking.* In order to assess WBA's ability to attribute an emotion or desire to someone else, we presented him with a task that was a simulation of four persons (the same four as in Test 3) watching a football match between WBA's favourite team and their local rivals. We explained to WBA that Uma supported the rival team (hereafter referred to as “opposite perspective”), that Dana had no preference and only watched the match out of politeness (“neutral perspective”) and that Peter would support the team playing best at the time, and might therefore change his mind during the match (“changing perspective”). We further explained that Peter judged as best the team that had most possession of the ball. The match was subdivided into 40 events (e.g. opportunity to shoot, goal, yellow card, penalty etc.). Each event was described visually on a drawing of the pitch and on an event card. The event card also represented (a) a graph indicating the percentage that the ball was possessed by each team (the histogram bars were coloured in the football teams’ official colours and changed from trial to trial according to which team possessed the ball most – the team playing best changed on 4 occasions during the match) and (b) the question with three choice responses. Half of the questions asked how someone (WBA himself, Uma, Dana or Peter) felt at that point of the match (emotion question) and half asked about the hopes of a particular person at that point of the match (desire question). In the case of the emotion questions, one choice response was “happy”, the second choice was “sad” or “angry” and the third was “doesn’t care”. For the desire question, one choice consisted in the action that would favour WBA’s team, the second choice was the action that would favour the opposition and the third choice was “doesn’t care”. A pre-test ensured that WBA understood the instructions and the way information was provided in the event cards.

*Results*

*Test 3 – Visual perspective taking.* Over 20 trials, WBA responded according to his own visual experience on all but one occasion, irrespective of the point of view he was asked to take (there were 70% egocentric errors). The task was then stopped on his request (he did not see the purpose of continuing what he considered to be a simple task). WBA’s performance was considerably worse than that of three age-matched control subjects who only made between 20% and 0% egocentric errors on the 20 first trials.

It could be argued that WBA’s difficulty to take someone else’s perspective resulted from the task being highly demanding in mental rotation skills. However, WBA was able to perform a mental rotation task requiring discrimination between normal and mirror-reflected letters, with the letters displayed across a range of orientations (20/20). Thus there was no evidence of him having a severe problem with mental rotation. Also note that WBA made egocentric errors (he never chose the wrong response that was not his own perspective). It appeared then that WBA had no notion that someone else would see the display differently (hence his comment that the task is too easy). Indeed, in a different session we simplified the display (from a 4 item to a 2 item arrangement) and asked WBA to sit at the other person's place. Despite this, he continued to make systematic egocentric errors.

*Test 4 – Social perspective taking.* WBA's overall score was quite poor (21/40 correct) with no difference when attributing an emotion (10/20 correct) or a desire (11/20 correct). Again, WBA's performance was impaired compared with three age-matched control subjects who only made between 2 and 0 errors.

WBA scored 8/10 when attributing an emotion or desire to himself (the 2 errors consisted in attributing a negative feeling – "sad" and "angry" – when a negative event happen to the opponent team, possibly reflecting a confusion between the two teams). When WBA had to give a perspective other than his own, he made 15/27 errors (56% errors), 14 of which were egocentric responses. There was also a trend for the changing perspective (i.e. Peter's perspective) to generate most errors (8 errors as compared to 5 errors for the neutral perspective and 4 errors for the opposite perspective). There are two possible accounts for this pattern of errors. Firstly, it is likely that the changing perspective placed higher incidental demands (e.g., inference from the graph who is the best playing team, shifting as the match goes along). Secondly, it is possible that the changing perspective placed higher self-perspective inhibition demands. Indeed, it could be argued that changing one's mind as to who to support in a football game (i.e. Peter) is unusual for a football fan, and might therefore be the most distant and thus the least salient other-perspective (the less salient the other's perspective, the more salient one's own perspective and hence the more demanding the inhibition processes).

## Discussion

In this paper, we report the case of a stroke patient, WBA, who showed difficulties reading someone else's mind following a right lesion affecting the frontal and temporal lobe. Strikingly, the patient's lesion localisation overlapped the right inferior frontal gyrus – a region implicated in inhibiting one's own perspective in neuroimaging studies (Vogeley *et al.*, 2001). In order to test the hypothesis that WBA's brain lesion affected a region that is necessary for self-perspective inhibition we presented the patient with two nonverbal false belief tasks that varied in self-perspective inhibition demands. WBA had difficulties only when the task was high in its demand for self-perspective inhibition. WBA also performed poorly in tests requiring him to make judgements about someone else's perceptual or emotional perspective or someone else's desire when he had his own perspective on the situation. Typically WBA's errors reflected his own perspective. The data suggest that WBA has a selective deficit in inhibiting his own perspective, supporting the hypothesis that the right frontal lobe (maybe especially the right inferior gyrus) is necessary for self-perspective inhibition.

## Inhibiting one's own perspective: a domain-specific process?

Some authors have suggested that the processing of different mental states (e.g., knowledge *versus* beliefs *versus* desires) relies on distinct functional and neural mechansisms (e.g., Saxe *et al.*, 2004). The present data, however, indicate that, as far as the inhibition of one's own perspective is concerned, there may be common processes for the different mental states. WBA made a high proportion of egocentric errors both on tasks where he was asked to attribute beliefs to someone else and on tasks in which he was asked to infer someone else's visual experience, desire or emotion. Thus, WBA's self-perspective inhibition deficit generalised across different kinds of mental states. Though it may be that WBA's lesion affected more than one mechanism sustained by adjacent brain regions, the pattern of association is striking. We also note that WBA's inhibition deficit was not confined to the social domain, since WBA was also impaired in non-social inhibition tasks such as the Hayling test of associative inhibition. This suggests that the right frontal lobe may play a general inhibitory role across a number of different domains (Aron *et al.*, 2003; Aron *et al.*, 2004a; Aron *et al.*, 2004b). This argument is consistent with studies from the developmental literature showing that young children's inhibition difficulties in mental state reasoning is observed across mental states such as beliefs and desires (Moore *et al.*, 1995) and is correlated with their general non-social inhibition abilities (Carlson and Moses, 2001; Carlson *et al.*, 2002).

**Inhibiting one's own perspective and inferring someone else's perspective: distinct functional and neural processes?**

For the first time in the neuropsychological literature, we have been able to distinguish the processes involved when we inhibit our own perspective from the processes when we infer someone else's perspective. These are two components of theory of mind that are typically confounded in classic false belief tasks. In the low inhibition task, the participant needed to realise that the woman in the video had a discrepant perspective – she had a false belief. In the high inhibition task, the participant needed not only to realise that the woman had a false belief, but also to infer a content for that belief that conflicted with their own knowledge. We anticipated that the high inhibition task would pose more problems for a participant who had difficulty with inhibitory control of self-perspective, and this was indeed the case for WBA. WBA made only one error in the low inhibition false belief task, indicating that he could, in principle, infer someone else's false belief. However, he performed poorly when required to suppress his own knowledge, in the high inhibition task. Indeed in this case WBA's performance was *below* chance, indicating that he was not guessing, but in fact making an egocentric error of judgement – asserting that the woman would behave *according to his own perspective*.

Interestingly, in previous studies, we reported the case of three patients who, in contrast to WBA, were impaired on the low inhibition false belief task (Samson *et al.*, 2004; Apperly *et al.*, in press). Because the low inhibition false belief task did not entirely eliminate all self-perspective inhibition demands, it could be that these patients were simply more impaired than WBA in self-perspective inhibition (having a stronger inhibition deficit, they would even fail the false belief task with the lowest inhibition demands). Alternatively, it could be that these patients' belief reasoning problem was different in nature from WBA's deficit, pointing to distinct functional and neural mechanisms for perspective taking as such on the one hand and, self-perspective inhibition on the other hand. Two kinds of evidence favour this latter account.

The first evidence comes from data on independent test of inhibitory control conducted on WBA and those patients selectively impaired on the low inhibition version of the false belief task (Samson et al., 2004). In a stimulus selection task, WBA showed a greater 'inhibition cost' than these other patients: there was a greater difference in errors between the inhibition and the control condition for WBA (a cost score of 0.25, 2.26 SD below the mean of controls; see Table 1), compared with the patients impaired on the low inhibition task (cost scores between 0 and 0.13, placing all the patients within the normal range). This suggests that WBA had a particular problem in selecting between competing stimuli, not shared with the other patients. In a response selection task, the inhibition error costs for the patients impaired on the low inhibition false belief task were 0, 0.38 and 1.56, whereas WBA's inhibition cost was 0.50. Here WBA was impaired to at least the same extent as two of the other patients (his score was 3.62SD below the controls' mean). Thus, on independent inhibition measures, WBA was at least as much if not more impaired than the three other patients. If the general level of inhibition impairment was the sole factor that differentiated WBA from the three other patients, we would have expected that WBA (who showed a stronger inhibition deficit) would fail both the low and high-inhibition false belief tasks, whereas the three other patients (with a milder inhibition deficit) would pass the low-inhibition false belief task. The results of our false belief tasks show exactly the opposite pattern. So, a difference in the degree of inhibition impairment cannot account for the different patterns of performance in the false belief tasks observed for WBA *versus* the three other patients.

The second piece of evidence suggesting that the three patients who failed the low inhibition false belief task have a qualitatively different problem from WBA comes from their different lesion sites. Samson *et al.* (2004) reported that selectively poor performance on low inhibition versions of the false belief task were associated with damage to the left temporo-parietal junction. In contrast, WBA's lesion affected the right frontal and temporal lobes. Strikingly, WBA's lesion overlapped the region of the right inferior frontal gyrus that has been shown to be specifically activated when healthy adults have to inhibit their own perspective (Vogeley *et al.*, 2001; see also: Ruby and Decety, 2003; Ruby and Decety, 2004). Thus, both the functional and anatomical evidence favours the hypothesis that distinct functional and neural mechanisms underlie, on the one hand, our ability to infer someone else's perspective (sustained by the (left) temporo-parietal junction) and, on the other, our ability to inhibit our own perspective (sustained by the right (inferior) prefrontal lobe).

To summarise, our study shows that we can isolate at the functional and neural level a self-perspective inhibition component as (1) a mechanism that *acts upon* self-perspective processing to inhibit it when it is irrelevant and (2) a mechanism that is a *necessary step* to correctly activate or represent someone else's perspective. We hope that by offering a way to isolate the self-perspective inhibition component we offer a means by which researchers can now address the specific processes involved in self and other-perspective taking without contamination of the self-perspective inhibition component. We believe that this is an important step if we are to decompose the basis of social reasoning.

## Conclusions

We report here the case of a patient WBA who was able to infer someone else's perspective as long as he himself did not hold a strongly conflicting self-perspective; however, in the latter case, WBA was markedly impaired on a range of tasks requiring inferences about someone else's beliefs, visual perspective, emotions and desires. The patient's lesion involved the right frontal lobe including the inferior frontal gyrus, a brain region that has previously been associated with self-perspective inhibition in a neuroimaging studies (Vogeley *et al.*, 2001) and that has also been specifically associated with response inhibition (Aron *et al.*, 2003; Aron *et al.*, 2004a). This case, shows the necessary role of the right (inferior) frontal lobe for inhibiting self-perspective and complements our previous finding of the necessary role of the left temporo-parietal junction when inferring someone else's perspective (Samson *et al.*, 2004; Apperly *et al.*, in press). Both findings constitute the first neuropsychological evidence suggesting that the inhibition of one's own perspective and the inference of someone else's perspective rely on distinct functional and neural mechansisms.

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**Table 1. WBA's general neuropsychological profile**

| | JQ's performance | | | |
|---|---|---|---|---|
| | 2002/2003 | | 2004 | |
| ***Orientation*** | | | | |
| In time and space (% correct) | 100 % | | - | |
| ***Long-term memory*** | | | | |
| Story recall – immediate free recall (% correct) (1) | **43 %** | | 80 % | |
| Story recall – immediate recognition (% correct) (1) | **67 %** | | 100 % | |
| Story recall – delayed free recall (% correct) (1) | **47 %** | | 97 % | |
| Story recall – delayed recognition (% correct) (1) | **87 %** | | 100 % | |
| Drawing recognition (% correct) (2) | 60 % | (-1.46 SD) | - | |
| ***Working memory*** | | | | |
| Digit forward span | 6 | | - | |
| Digit backward span | 4 | | - | |
| Digit recall after manipulation (% correct) | **79 %** | **(-5.76 SD)** | 98 % | (-0.23 SD) |
| Digit recall after interference (% correct) | 90 % | (+0.81 SD) | - | |
| Digit recall after updating (% correct) | **67%** | **(-2.20 SD)** | **60 %** | **(-2.90 SD)** |
| ***Attention and executive function*** | | | | |
| Sustained attention (% correct) (3) | **43 %** | | **43 %** | |
| Selective attention (no. errors) (4) | **117** | **(< Perc. 1)** | 25 | (Perc. 50) |
| Inhibition – stimulus selection (error cost) | **0.25** | **(-2.26 SD)** | - | |
| Inhibition – response selection (error cost) | **0.50** | **(-3.62 SD)** | - | |
| Inhibition – Hayling test (total scaled scores) (5) | | | **8** | **(Impaired)** |
| Shifting – alternation of focus of attention (error cost) | **5.5** | **(-13.49 SD)** | - | |
| Shifting – alternation of arithmetical operation (error cost) | 1 | (-0.77 SD) | - | |
| Shifting – TMTb (execution time) (6) | 122 sec. | (Perc. 25-50) | - | |
| Brixton (% correct) (5) | **37 %** | **(Impaired)** | - | |
| ***Language*** | | | | |
| Written synonym judgement (% correct) | 93 % | | - | |
| Auditory comprehension of verbs and adjectives (PALPA 57, % correct) (7) | **85 %** | **(-6.02 SD)** | - | |
| Auditory sentence/picture matching (PALPA 55, % correct) (7) | **65 %** | **(Impaired)** | - | |
| Written sentence/picture matching (PALPA 56, % correct) (7) | **60 %** | **(Impaired)** | - | |

Note: Scores in bold are impaired. WBA's performance when compared to control subjects is displayed in brackets.
(1) Taken from the Birmingham Cognitive Screen (in preparation).
(2) Test d'apprentissage progressif de dessins sans signification (Violon and Seyll, 1984).
(3) Elevator Counting Task (Robertson *et al.*, 1994).
(4) D2 Test (Brickenkamp, 1966).
(5) The Hayling and Brixton Tests (Burgess and Shallice, 1997).
(6) Trail Making Test (Reitan, 1958).
(7) Psycholinguistic Assessment of Language processing in Aphasia (Kay *et al.*, 1992).

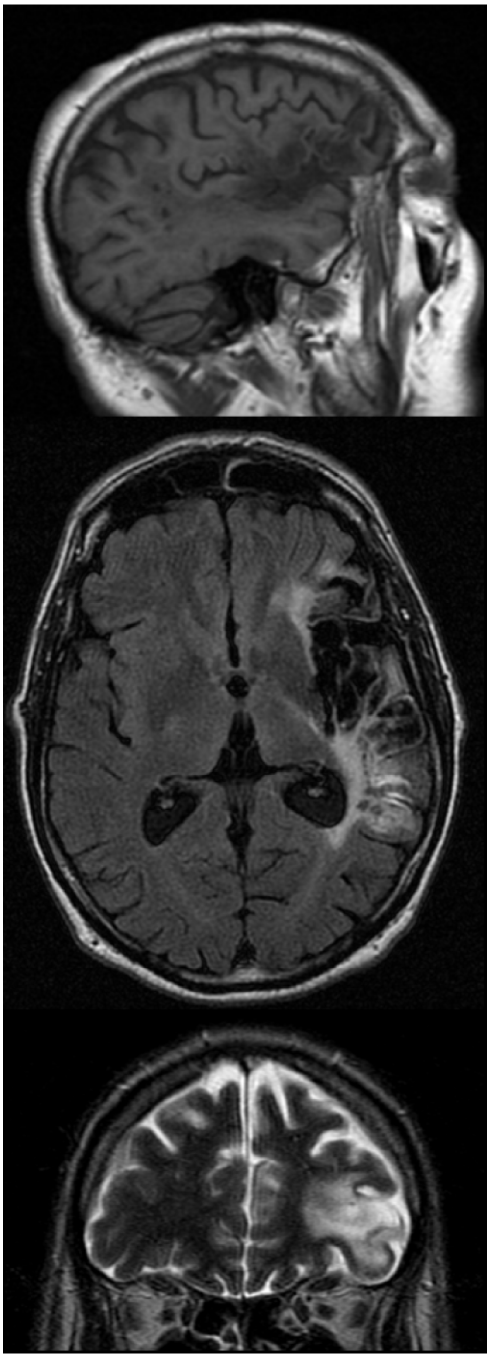

Figure 1. WBA’s MRI scan result showing his right lesion.

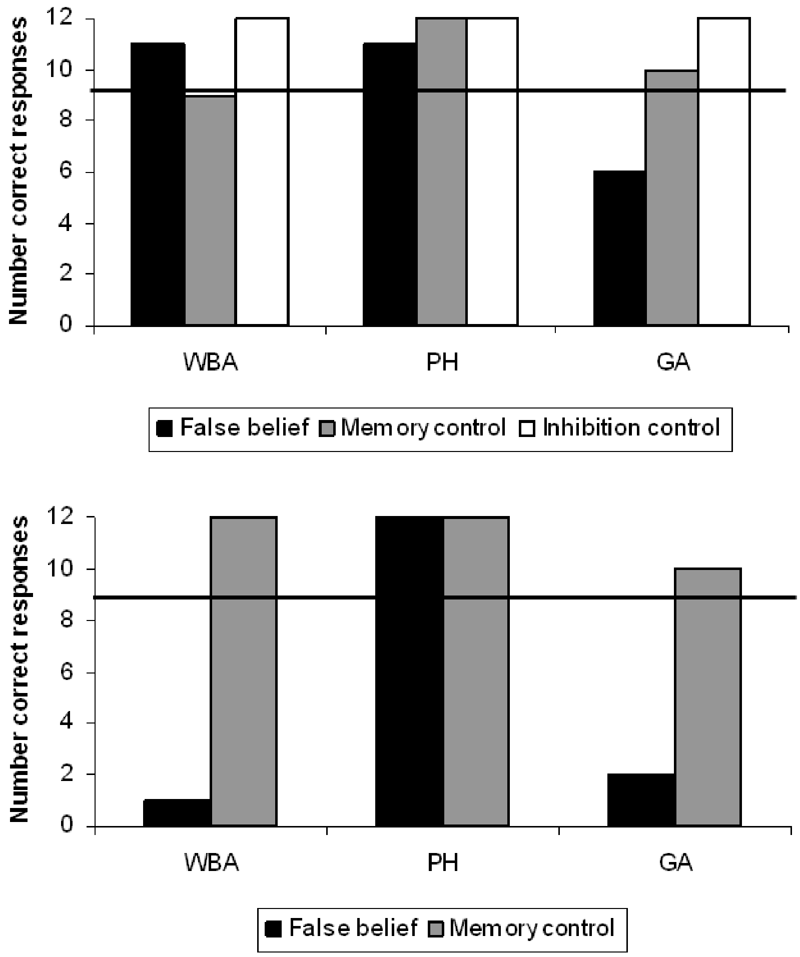


Figure 2. WBA as well as two control patients' performance on the low-inhibition (upper-graph) and high-inhibition (lower graph) false belief tasks. A score of more than nine correct answers is significantly above chance level (one-tailed *P*-value associated with getting 10/12 correct = 0.019 by binomial test)

**Supplementary Method – control trials for the low- and high-inhibition false belief tasks**

*Control items in the low inhibition false belief task.* The memory control videos were exactly the same as the false belief videos, except that the sequence of two events was reversed, i.e. the woman pointed to one of the boxes before leaving the room. The participants could then infer where the green object was without inferring that the woman had a false belief, but participants did need to update their memory of the object's location after the boxes had been swapped. The inhibition control video showed the same sequence of events as the false belief video but instead of swapping the boxes, the man performed a visible transfer of the green object from one box to the other. In order to locate the green object, participants did not need to infer that the woman had a false belief (they saw where the green object was transferred) but they needed to inhibit pointing to the (wrong) box indicated by the woman. The filler-trials were added to minimise the possibility that participants solved the false belief trials by superficial means (e.g. always responding to the box opposite from where the woman pointed).

*Control items in the high inhibition false belief task.* The memory control videos were exactly the same as the false belief videos, except that, while the woman was outside, the man took out the green object from the box and put it back in the same box (thus there was no change in the object's location). The participant could infer which box the woman would open first simply by remembering where the green object was located. As for the low- inhibition false belief task, filler-trials were added to minimise the possibility that participants solved the false belief trials by superficial means.