Severe Impairment in Grammar Does Not Preclude Theory of Mind

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Abstract

Debates about the role of language in human thinking are increasingly prominent in the cognitive sciences. There are claims that certain forms of reasoning can only be performed through access to the resources of the language faculty. In particular, a component of social cognition involving the representation of the mental states of others ('theory of mind' reasoning) has been claimed necessarily to involve propositions of natural language. A recent case study reported a man (SA) with severe agrammatic aphasia who was unable to understand or produce language propositions in any modality of language use, but who was able to complete theory of mind tasks. We report a replication of this finding using a modified picture theory of mind task with a second patient (MR). Despite severe aphasia and impaired performance on a test of executive function, MR demonstrated retained theory of mind reasoning. These results reveal the functional autonomy of theory of mind from the capacity for propositional/grammatical language, and support its independence from executive function.

Introduction

Strong claims have been made for the role of natural language sentences in various forms of reasoning. In particular, it has been maintained that to make inferences about another person's beliefs, 'theory of mind' (ToM), crucially involves natural language. A key proposal is that ToM reasoning is mediated by the ability to process sentences (Carruthers, 1996; Astington and Jenkins, 1999). A standard method of testing for ToM involves 'false-belief' tasks. In a 'Smarties', or changed container task, the subject is presented with a familiar container but the contents are revealed and shown to be incongruent with the external packaging (e.g. the Smarties tube contains pencils). The subject is then asked what a third person who saw the package (but not the contents) would believe it contained. According to one language mediation account (de Villiers and de Villiers, 2000; Tager-Flusberg, 2000), ToM reasoning requires the embedding of one (false) proposition within another (e.g. John thinks that there are Smarties in the tube). By this account, the grammatical system of language is the only representational code possessed by the human mind that is capable of handling this embedded format of reasoning.

Some collateral evidence for language mediation in ToM reasoning can be found in functional imaging studies. Extensive activation of left temporal lobe structures, including superior temporal and temporoparietal junction areas during ToM tasks have been identified (Fletcher *et al.*, 1995; Goel

et al., 1995). Activations of perisylvian language zones have also been found in picture-based tasks that do not require language decoding or production (Brunet *et al.*, 2000), thus implicating a role for language in mediating ToM performance that extends beyond a simple input/output function to central cognition.

In addition to the role of language in ToM, a second theoretical issue concerns the relationship between ToM and executive functioning. Investigations of autistic disorders have identified ToM deficits, but also parallel impairment on tests of executive function. This has led to the claim that pre-frontal cortex executive functions are implicated in ToM reasoning (Ozonoff et al., 1991; Frye et al., 1995, 1996; Perner and Lang, 1999). Happé et al. (2001) report the case of a patient with a bilateral surgical lesion of the anterior limb of the internal capsule, resulting in a disconnection of midline thalamic fibres from the orbitofrontal cortex. This patient displayed co-occurring ToM and executive function deficits. Similarly, functional imaging and lesion studies suggest that there might be a close anatomical and/or functional relationship between ToM and executive functions. Imaging and lesion studies indicate that orbitofrontal, medial pre-frontal cortical zones together with the amygdala may be critical to sustaining ToM reasoning (Fletcher et al., 1995; Goel et al., 1995; Stone et al., 1998; Baron-Cohen et al., 1999a; Brunet et al., 2000; Gallagher et al., 2000; Stuss

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et al., 2001). An alternative view suggests that ToM is underpinned by a dedicated and independent neural system, components of which are anatomically close to—but functionally distinct from—the neural circuitry that underpins aspects of executive function. Baron-Cohen *et al.* (1999b), Fine *et al.* (2001) and Lough *et al.* (2001) report cases of a dissociation between ToM and executive functions that would appear to support this second position. These investigations reported instances of impaired ToM performance but retained executive function. However, in order to establish the autonomy of ToM reasoning from executive function, it is necessary to identify cases of retained ToM in the face of executive function impairment.

Evidence from aphasia can inform debates on the role of language in various forms of reasoning. However, careful consideration of the design of studies is necessary, and previous studies have often been imprecise in defining the characteristics of the patients recruited, or in isolating areas of reasoning for which serious claims of language mediation can be advanced (Siegal *et al.*, 2001). For example, aphasic patients often with residual grammatical and lexical ability have been studied, with the possibility that, although impoverished, the patients still had access to simplified or protolanguage propositions. Similarly, performance might be investigated on visuospatial reasoning tasks, with no clear rationale as to why performance on such a task might be mediated by language.

In a recent study, we sought to address these issues (Varley and Siegal, 2000). A man with severe agrammatic aphasia (SA), to the extent that he is unable to access language propositions in any modality of language use, was tested on tasks for which specific claims for language mediation had been advanced, namely ToM reasoning tasks. Despite his profound impairment in grammatical language, SA retained ToM abilities, and also demonstrated proficiency on tests of causal understanding. In this paper, to support further the independence of ToM reasoning and grammatical ability, we report a second case of a man with severe aphasia (MR).

Subject

MR is a 60-year-old right-handed male who was tested 3 years post-onset of a left hemisphere cerebrovascular accident. He was educated to degree level and pre-morbidly had been a lecturer in a further education college. A computed tomography (CT) scan revealed damage consistent with a proximal occlusion of the left middle cerebral artery, with damage to lenticular striate cortex, basal ganglia and internal capsule and cortical damage to the perisylvian area. This included lesion of the superior temporal gyrus, extending to parietal regions, together with damage to the inferior frontal gyrus and the operculum (Fig. 1).

MR resembled the previously reported case SA to the extent that he had severe aphasic difficulties and an inability to understand or produce language propositions in all modalities of language use. MR displayed residual lexical knowledge, but marked impairments of grammatical knowledge. The performance of MR on language tests in lexical and grammatical domains is displayed in Table 1.

In lexical processing, MR showed residual ability in auditory and orthographic word comprehension and in spoken picture naming, particularly on tests using picture materials. Written naming was profoundly impaired. In grammatical processing, MR showed preservation of the ability to make grammaticality judgements on both embedded and nonembedded sentences. This was particularly true of spoken sentences, where prosodic information may have assisted the judgement of grammaticality. However, beyond the ability to judge the adequacy of the surface structure of sentences, on all other measures of grammatical processing, MR responded in the same manner as SA. MR was unable to determine the structural/thematic role a noun phrase performed in a sentence as revealed by scores at chance level on a test of reversible sentence comprehension across both spoken and written modalities. The sentences used in this test were all non-embedded, with half being simple subjectverb-object active sentences ('The man killed the lion.') and therefore simpler than the proposed embedded format of ToM propositions ('The woman thought that the man killed the lion.'). MR also had marked difficulties on a test of verb comprehension. He had a digit span of three items, which suggests that limited phonological working memory could not account for his sentence comprehension difficulties (Martin, 1993). Spontaneous speech consisted largely of stereotypic forms, and sentence fragments, with minimal evidence of ability to construct novel language propositions (see Table 2).

Methods

MR completed a series of tasks that aimed to assess ToM understanding and causal reasoning. The ability to understand first-order false belief was investigated using a new picturebased task format that minimized demands on language both in understanding probe questions and in producing responses (Custer, 1996; Woolfe *et al.*, 2002). The ability to understand causal relationships was examined by a causal association test and the Wechsler Adult Intelligence Scale (WAIS) picture arrangement test (Wechsler, 1981). The relationship between executive function and ToM was explored through completion of the Wisconsin Card Sorting Test (WCST) (Heaton *et al.*, 1993). The WAIS subtest and the WCST were administered and scored by standard procedures.

Causal association test

MR was presented with a picture card that depicted an event on the left-hand side (for example, a car crashed into a tree). On the right-hand side of the card there were three pictures (the target—an alcoholic drink, and two semantic associates to elements of the event picture—an axe and a helicopter). MR was required to indicate the likely cause of the event. In three training trials, the cue 'why?' was printed on the



Fig. 1. Computed tomography images showing the extent of infarction, with damage across the perisylvian language areas and extending into parietal regions.

Table 1. Performance of MR on measures of language processing

Test	MR score	Chance score
Pyramids and Palm Trees (three picture version)	46/52*	26
PALPA test 47 (spoken word-picture matching)	33/40*	8
PALPA test 48 (written word-picture matching)	31/40*	8
ADA spoken synonym judgement	137/160*	80
ADA written synonym judgement	141/160*	80
PALPA test 54 (spoken picture naming)	39/60	_
PALPA test 54 (written picture naming)	1/20	_
Auditory grammaticality judgements		
Non-embedded sentences	40/40*	20
Embedded sentences	34/40*	20
Written grammaticality judgements		
Non-embedded sentences	34/40*	20
Embedded sentences	26/40	20
Spoken reversible sentence-picture matching	55/100	50
Written reversible sentence-picture matching	57/100	50
PALPA test 57 (auditory comprehension of verbs and adjectives)	22/41	20.5
PALPA test 13 (digit span)	3 items	-

*Significantly above chance at the P < 0.01 level.

The tests were taken from the Psycholinguistic Assessments of Language Processing in Aphasia (PALPA) battery (Kay et al., 1992), the ADA auditory comprehension battery (Franklin et al., 1992), and the Pyramids and Palm Trees Test (Howard and Patterson, 1992). Other tests were designed for the purposes of this study (grammaticality judgements and the reversible sentence-picture matching tests). The grammaticality judgement tests require the participant to categorize spoken or written sentences as grammatical or ungrammatical. The reversible sentence comprehension test involves matching a spoken or written sentence to the picture that correctly depicts the agent-patient relationship and contains equal numbers of active and passive sentences (e.g. the man killed the lion/the man was killed by the lion). A patient who is using an order-of-mention strategy in determining which noun is playing which role ('assume first mentioned noun is the subject/agent') will therefore achieve a chance score on the test. Digit span (PALPA 13) was tested in a recognition paradigm, versus the usual verbal recall of digits, in order to minimize lexical retrieval and speech production factors in performance.

Table 2. Examples of spontaneous speech output from MR

Stereotypes	Sentence fragments	Generative
It's OK (now/there/though) That's OK (now) That's nice (though) It's awful (though) It's bad I (really) don't know I can't explain (it/now) I think (so) You know Oh look at that Anyway All the time	Is the Also he's It's It's the But that Is there That is It's just	You know X Charles But cancer Bikes Dentist as well

The parentheses indicate an optional element in a stereotype.

test card and the task explained to the participant. On the 15 test items, MR's attention was directed to the event picture and he was asked 'why did this happen?'.

Picture false-belief test

The ToM tasks consisted of 'thought picture' first-order falsebelief tasks (Custer, 1996; Woolfe *et al.*, 2002). These require understanding of the distinction between 'think' and 'really', both low imageability words that are likely to be susceptible to aphasic comprehension disturbances. Therefore, prior to the tasks, the predicates were trained in four trials. MR was presented with two pictures of characters thinking about reality (e.g. 'John is really a vicar. He thinks about being a vicar.'), or two characters who were fantasizing (e.g. 'Mary is really a secretary. She thinks about being a rock star.'). The predicates were associated to an appropriate picture, with a thought bubble to represent 'think', and a solid frame to represent 'really'. MR demonstrated comprehension of the distinction between predicates in response to the questions 'what does John/Mary think about?' 'what is John/Mary really?' by placing an appropriate picture card into the thought bubble and solid frame, respectively.

Following the training of the predicates, five paired pictures were presented, with one card representing a true-belief scenario and the second, a false-belief scenario. For example, one pair depicted a boy fishing with a fish visible in the water, but the fishing hook hidden by weeds. The weeds were then removed to reveal the object on the hook. In the true-belief condition, this was a fish; and in the false-belief condition, it was a boot. The subject was then asked a belief question ('what does the boy think he has caught?') or a reality question ('what has the boy caught really?'). Belief questions were prompted by a card depicting the character with a thought bubble, and reality questions were accompanied by the character beside a solid frame. One member of each paired set of pictures was randomly allocated to block one or block two of testing, with both blocks being administered in the same session. MR was presented with a pictured scenario, and then presented with the belief and reality questions in counterbalanced order. MR responded to each question by selecting a picture from a display of four response cards, and placing it inside the thought bubble or the reality box. The picture choices included reality, a false belief, and two thematically linked foils. In order to pass a trial, both belief and reality responses had to be correct.

Results

MR displayed retained ability on all tasks, with the exception of the WCST, where his performance was in the severely impaired range. On the causal association test, MR selected the correct cause of the event on 14/15 trials. His score on the story arrangement test of the WAIS was 12/20 (63rd percentile of a normal age-matched population). MR also demonstrated intact ToM reasoning, achieving perfect scores (5/5) on both true-belief and false-belief conditions of the picture ToM test.

On the WCST, MR failed to complete a single category in 128 trials. He made 68 erroneous categorizations across these trials and this error score places him on the 5th percentile of an age- and education-matched normative sample. MR generally attempted to sort by principles of number and form, with a strong tendency to perseverate on number. The possibility that an impairment of colour perception had influenced his performance was explored through the administration of an Ishihara Test (Ishihara, 1983), and a task involving associating a black and white line drawing of an object with its usual colour (e.g. carrot-orange). The Ishihara Test indicated some mild colour processing problems, whilst the object-colour association test revealed perfect performance. In view of the possibility of an early stage colour processing deficit, a revised WCST was devised. This was designed on identical principles to the WCST, but removed the colour variable from the task—replacing colour with a 'fill in' variable (stripes, diamonds, solid, blank). In this revised task, MR was able to complete a single category, but was then unable in 40 subsequent trials to establish the new sorting criterion and the task was abandoned.

Discussion

The findings on ToM reasoning and causal understanding from patient MR are consistent with those of the earlier study with SA (Varley and Siegal, 2000). These are also in keeping with the results of studies with children that have shown the presence of ToM and other abstract reasoning abilities despite specific impairment in grammatical aspects of language (Leslie and Frith, 1988; van der Lely et al., 1998). The pattern of results suggests that ToM and causal understanding can be achieved without the support of grammatical knowledge, and that reasoning about the beliefs of others does not by necessity take place in explicit propositions of natural language. Both patients displayed profound disruption in understanding and in constructing propositions across all modalities of language use, but despite these linguistic impairments, both were able to display a convincing level of performance on tasks involving reasoning about ToM and causality.

The dissociation between ToM and executive function (as measured by the WCST) displayed by MR is noteworthy. Cases of intact executive function but impaired ToM have been reported (Fine *et al.*, 2001; Lough *et al.*, 2001), but MR demonstrates the reverse dissociation, with impaired executive function, but retained ToM performance. However, the evidence of the dissociation in MR is based on his performance on a single task involving a sizeable visuospatial component. MR has a large parietal lesion, and also subcortical damage to association fibres running between posterior sensory zones and the frontal lobe. His difficulties on an executive function task that modulates aspects of visuospatial cognition might be due to a disconnection problem, for example, disruption of the dorsal stream of visual processing (Mishkin *et al.*, 1983).

Despite these qualifications, MR is severely impaired in central aspects of grammar and executive function. Yet these impairments do not preclude ToM reasoning.

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R. Varley, M. Siegal and S. C. Want Abstract

Debates about the role of language in human thinking are increasingly prominent in the cognitive sciences. There are claims that certain forms of reasoning can only be performed through access to the resources of the language faculty. In particular, a component of social cognition involving the representation of the mental states of others ('theory of mind' reasoning) has been claimed necessarily to involve propositions of natural language. A recent case study reported a man (SA) with severe agrammatic aphasia who was unable to understand or produce language propositions in any modality of language use, but who was able to complete theory of mind tasks. We report a replication of this finding using a modified picture theory of mind task with a second patient (MR). Despite severe aphasia and impaired performance on a test of executive function, MR demonstrated retained theory of mind reasoning. These results reveal the functional autonomy of theory of mind from the capacity for propositional/grammatical language, and support its independence from executive function.

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Primary diagnosis of interest

Severe aphasia

Author's designation of case MR

Key theoretical issue

- Evidence for the independence of theory of mind reasoning and propositional language
- Evidence of retained theory of mind reasoning in the face of impairment of executive function

Key words: severe aphasia; thinking; theory of mind; executive function

Scan, EEG and related measures

Computed tomography

Standardized assessment Neuropsychological investigation

0.4

Other assessment

Picture theory of mind test, causal association test

Lesion location

• Proximal occlusion of the left middle cerebral artery, with damage to lenticular striate cortex, basal ganglia and internal capsule and cortical damage to the perisylvian area

Lesion type

Cerebrovascular accident

Language

English