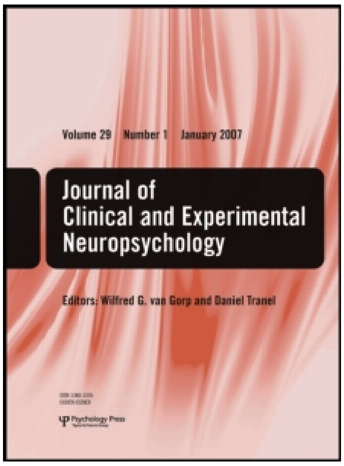

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False-belief understanding in frontotemporal dementia and Alzheimer's disease

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The ability to understand other people's behavior in terms of mental states, such as beliefs, desires, and intentions, is central to social interaction. It has been argued that the interpersonal problems of patients with behavioral variant of frontotemporal dementia (FTD-b) are due to a dysfunction of that system. We used first- and second-order false-belief tasks to assess theory-of-mind reasoning in a group of patients with FTD-b and a cognitively matched group of patients with Alzheimer's disease (AD). Both patient groups were equally impaired relative to a healthy elderly group in the cognitively demanding second-order false-belief tasks, revealing that cognitive demands are an important factor in false-belief task performance. Both patient groups reached ceiling performance in the first-order false-belief tasks with minimal cognitive demands, despite the striking difference in their social graces. These results suggest that a conceptual deficit in theory of mind—as measured by the false-belief task—is not at the core of the differences between FTD-b and AD.

Keywords: Theory of mind; Cognitive processes; Modularity; Development; Neuropsychology.

In recent years, the neural bases of social cognition have become the focus of intense research. One area that has received a lot of attention is *theory of mind*. Also known as *folk psychology* or *mentalizing*, theory of mind refers to the ability to understand and predict other people's behavior on the basis of mental states such as beliefs, desires, and intentions. It also refers to knowledge regarding the attributes of mental states—for example, that beliefs do not always match reality, that people cannot intend things they believe they are incapable of doing, and so forth (Astington, Harris, & Olson, 1988). Although theory-of-mind reasoning has been explored in a variety of paradigms, the litmus test continues to be the false-belief task (Wellman, Cross, & Watson, 2001).

In the first-order false-belief task, participants are asked to predict the behavior of a character who holds a mistaken belief about the state of the world. In the classic story (Wimmer & Perner, 1983), Maxi puts his chocolate in the cupboard and goes outside to play. While he's gone, his mother moves the chocolate to the drawer. Participants are asked to predict where Maxi will look for his chocolate upon his return. Correctly predicting "cupboard" requires a conceptual understanding that the mind is a representational system: The mind may represent reality falsely, and that false representation would in turn guide behavior.

In normally developing children, the conceptual understanding necessary for the first-order false-belief task emerges around 4 years of age

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(Wellman et al., 2001). The second-order false-belief task is a more complex version of the task, requiring participants to infer the thoughts of a character who holds a mistaken belief about another character's knowledge. In this version of the task, for example, Maxi comes back inside and, unbeknownst to his mother, sees her move his chocolate. Participants are asked to predict where the mother—who does not know of Maxi's updated knowledge—will think he will look for his chocolate. The second-order false-belief task taps onto many general cognitive abilities, including the ability to integrate relational information, filter distracting lures, and hold information in working memory. Consistent with the increased demands posed by the second-order false-belief task, normally developing children do not succeed in this task until the age of 5 or 6 (Coull, Leekam, & Bennett, 2006; Perner & Wimmer, 1985; Sullivan, Zaitchik, & Tager-Flusberg, 1994).

Neuroimaging studies have started to explore the neural bases of false-belief understanding. Many of those studies have attempted to find brain areas specifically involved in theory of mind in support of the claim that mental state attribution is domain specific. Philosophical issues aside on the fruitfulness of framing the problem this way, mental-state attribution tasks consistently activate a network of areas that usually includes the amygdala, temporo-parietal junction, and orbito-frontal and medio-frontal areas (Saxe, Carey, & Kanwisher, 2004; Saxe & Powell, 2006). However, some of these areas are also activated when mental-state attribution is not required, and this has led some researchers to raise doubts on the domain specificity of theory of mind (Mitchell, 2008). A similar situation arises from studies of patients with focal brain injury. Some scientists have argued that deficits in theory of mind are independent of executive functions (Fine, Lumsden, & Blair, 2001; Rowe, Bullock, Polkey, & Morris, 2001) while others have shown evidence that performance in theory-of-mind tasks varies as a function of demands on memory (Stone, Baron-Cohen, & Knight, 1998), executive function (Channon & Crawford, 2000), and language (Apperly, Samson, Chiavarino, & Humphreys, 2004; for a review see Apperly, Samson, & Humphreys, 2005). A close link between theory of mind and general cognitive abilities receives support from developmental studies in normal populations (Carlson & Moses, 2001).

Understanding that behavior is dependent on beliefs about reality rather than on reality itself constitutes a major developmental achievement. It is an achievement without which it becomes impossible to function normally in the social world. For this reason, neuropsychological research on theory-of-mind reasoning has focused on patient populations that exhibit impaired social skills. Most of these studies have been in patients with abrupt lesions, such as stroke and trauma, but more recent research has also focused on progressive diseases such as the behavioral variant of frontotemporal dementia (FTD-b; Gregory et al., 2002; Lough, Gregory, & Hodges, 2001; Snowden et al., 2003).

FTD-b is characterized by changes in personality, impaired social skills, poor decision making, lack of empathy, and lack of insight (Fernandez-Duque & Black, 2005, 2007; Grossman, 2002; McKhann et al., 2001; Mychack, Rosen, & Miller, 2001; Neary, Snowden, Gustafson, Passant, et al., 1998). At the neural level, FTD-b is characterized by atrophy of orbito- and medio-frontal cortex, anterior temporal pole, and amygdalar complex (Bocti, Rockel, Roy, Gao, & Black, 2004; Brun, 1987; Rosen et al., 2002). All these areas participate in emotion, which raises the possibility that socially inappropriate behavior in FTD-b stems from impaired regulation of emotions rather than from impaired theory-of-mind processing (Rahman, Sahakian, Hodges, Rogers, & Robbins, 1999). Consistent with this view, lesion studies in animals show that inappropriate social behavior can occur independently from theory-of-mind abilities. For example, orbitofrontal and amygdala lesions lead to serious social impairment even in species for which mental state attributions are not part of the normal social repertoire (Bachevalier, Málková, & Mishkin, 2001; Hadland, Rushworth, Gaffan, & Passingham, 2003; Rosvold, Mirsky, & Pribram, 1954).

One way to investigate whether the impaired social graces of FTD-b patients stem from a faulty theory of mind is to compare their performance in false-belief tasks to the performance of patients with similar cognitive deficits but spared social skills. Patients at early stage of Alzheimer disease (AD) fit this description. Performance of FTD-b and AD patients should also be compared to that of healthy elderly adults, to assess the contribution of cognitive demands to false-belief impairment in dementia (i.e., cognitive deficit hypothesis). This comparison is particularly important for the second-order false-belief task, a more complex and cognitively demanding task. FTD-b and AD patients often have cognitive deficits that may contribute to poor performance in the false-belief task, including concrete thinking, impaired language comprehension, poor relational memory, poor analogical reasoning, and executive function deficits (Morrison et al., 2004; Rhee, Antiquena, & Grossman, 2001; Waltz et al., 1997).

There is one report in the literature comparing first- and second-order false-belief reasoning in FTD-b, Alzheimer's disease, and healthy aging (Gregory et al., 2002). Consistent with a cognitive deficit hypothesis, both patient groups were equally impaired in their second-order false-belief performance, relative to the healthy elderly group. More importantly, the FTD-b group was impaired in the first-order false-belief task, in contrast to the near-ceiling performance of the AD group. This latter result raises the intriguing possibility that at the core of FTD-b's problems lies a conceptual deficit in understanding the representational nature of the mind. Our study aimed to further explore this possibility, testing first-order false-belief understanding with a more extensive battery.

We asked whether FTD-b's deficit in false-belief understanding could be fully accounted for by a conceptual deficit in mentalizing or whether this deficit is better explained by the cognitive demands of the tasks themselves. To test these competing hypotheses, we reduced the cognitive demands of the first-order false-belief task by using the simplest tasks available in the developmental literature, and we compared performance of the FTD-b group to that of a cognitively matched group of patients with Alzheimer's disease. We reasoned that if patients with FTD-b were impaired in mentalizing as previous studies have suggested, their deficit should be evident even under the reduced cognitive load of our first-order false-belief battery. To further assess the contribution of cognitive deficits to false-belief performance we also administered a second-order false-belief task and compared both clinical groups' performance to that of a group of healthy adults.

METHOD

Participants

A total of 11 patients with behavioral variant of frontotemporal dementia (FTD-b), 17 patients with Alzheimer's disease (AD), and 12 age-matched normal controls participated in the study. Only patients with mild dementia were selected, based on a cutoff score of 20 in the Mini-Mental State Examination.[1] The AD group was significantly older than the FTD-b group, consistent with FTD-b being a presenile dementia.[2]

All three groups completed a neuropsychological assessment within 6 months of their assessment in theory-of-mind tasks (see Table 1). As expected, both patient groups were impaired relative to the normal controls in most domains. More importantly, the patient groups were well matched in most domains. Exceptions included the verbal fluency task, in which the FTD-b group performed significantly worse than the AD group, and the delayed visual reproduction task and the California Verbal Learning test, in which the FTD-b group performed better than the AD group. These results are consistent with previous findings from the literature (Hodges et al., 1999; Kramer et al., 2003).

[1]Patients were recruited primarily through the Sunnybrook Dementia Study at Sunnybrook Health Science Centre at the University of Toronto, where the project received approval from the Ethics Board. Consent for participation in the study was obtained from the patients and their caregivers. A cognitive neurologist (S.E.B.) assessed all the patients. A history was taken from the patient and from a close relative/caregiver. Besides meeting criterion for behavioral variant of FTD established by the work group on frontotemporal dementia and Pick's disease (McKhann et al., 2001), all the FTD-b patients presented with a corroborated history of progressive decline in social interpersonal conduct. Patients presenting primarily with language complaints (progressive nonfluent aphasia or semantic dementia) were excluded. All the AD patients met criterion for probable Alzheimer's disease, as established by the workgroup of the National Institute of Neurological and Communicative Disorders and Stroke–Alzheimer's Disease and Related Disorders Association (NICNCDS-ADRDA; McKhann, Drachman, Folstein, Katzman, Price, & Stadlan, 1984). For 1 FTD-b patient, atypical Alzheimer's disease was in the differential diagnosis, and for another corticobasal degeneration was in the differential diagnosis. Behavioral symptoms were assessed in the FTD-b group with the Frontal Behavioral Inventory (Kertesz, Nadkarni, Davidson, & Thomas, 2000). This is a standardized 24-item questionnaire that assesses the major behavioral changes characteristic of FTD-b and has shown some reliability in discriminating FTD-b from other dementias. The questionnaire was completed with the assistance of the patient's caregiver. Consistent with the clinical diagnosis of FTD-b, all the patients had abnormal scores (cutoff 30; range 35–48). Signs of neuropsychiatric dysfunction included disinhibition, aberrant motor behavior, apathy, and changes in eating behavior. To rule out contributions from other pathologies, magnetic resonance imaging (MRI) was performed on both patient groups with a 1.5-tesla GE Signa scanner using standard protocol (Callen, Black, Gao, Caldwell, & Szalai, 2001). Apart from atrophy consistent with the patients' dementia, the scans showed no other pathology.

[2]Groups were not matched by age because that would have caused a distortion in the sampling of the AD population. Instead, age differences were explored in a preliminary analysis that compared theory-of-mind performance of "young" and "old" participants, defined by the age median split for each group. No age effect was observed in this analysis.

TABLE 1
Demographic, neuropsychiatric, and neuropsychological information

	Max. score	*Healthy elderly*	*AD*	*FTD*
Age (years)		68.7 (8.8)[a]	69.4 (5.7)	60.6 (7.2)[b]
Sex: male–female ratio		6/6	11/6	8/3
Years of education		15.3 (4.0)	15.9 (3.9)	16.1 (3.3)
Months since reported onset[c]		n/a	47 (41)	41 (34)
Frontal Behavioral Inventory	72	n/a	n/a	42 (4.7)
NART-R FS IQ*		115.9 (3.5)[a]	110.8 (9.4)	107.4 (9.4)
MMSE*	30	28.8 (0.8)[a,d]	24.9 (2.1)	26.4 (1.6)
DRS (total)*	144	141 (1.3)[a,d]	124.0 (11.8)	126.4 (8.0)
Boston Naming*	30	27.7 (1.3)[a,d]	22.5 (8.1)	23.7 (5.6)
WAB comprehension*	10	9.98 (.05)	9.88 (0.2)	9.80 (0.4)
Verbal fluency (FAS)*		48.1 (15)[a,d]	31.6 (14)	21.0 (10)[b]
Semantic fluency*		19.1 (5)[a,d]	12.5 (5)	11.3 (5)
Forward digit span*	12	9.4 (1.9)	8.2 (2.0)	8.0 (2.2)
Backward digit span*	12	7.8 (2.0)[a,d]	5.2 (2.4)	4.9 (2.6)
Trails A*	n/a	37.1 (8)[d]	60.2 (34)	53.2 (29)
Trails A error*		0.0 (0)	0.07 (0.2)	0.0 (0)
Trails B*	n/a	71.2 (21)[a,d]	153 (81)	160 (105)
Trails B error*		0.0 (0)[a,d]	1.3 (1.3)	0.88 (1.1)
CVLT Acquisition*	80	46.3 (7.4)[a,d]	24.1 (8.9)	34.2 (8.1)[b]
CVLT Delayed Free Recall*	16	8.9 (3.1)[a,d]	1.5 (1.7)	5.6 (2.6)[b]
Ravens[e]*	36	32.6 (1.2)[a,d]	25.1 (6.8)	24.4 (7.6)
Line Orientation task[f]*	30	26.0 (5)[a,d]	21.3 (8)	18.4 (6)
Visual memory immediate[f]*	41	32.8 (3)[a,d]	18.7 (8)	19.4 (5)
Visual memory delayed[f]*	41	25.7 (4)[a,d]	2.8 (5)	10.3 (9)[b]
Rey Copy[f]*	36	34.2 (2)[a,d]	25.9 (10)	25.9 (6)

Note. AD = Alzheimer's disease. FTD = frontotemporal dementia. NART-R, National Adult Reading Test-Revised; FS IQ = full-scale IQ; MMSE, Mini-Mental State Examination; DRS, Dementia Rating Scale; WAB, Western Aphasia Battery; CVLT, California Verbal Learning Test. Standard deviations in parentheses.
[a]Healthy elderly significantly different from FTD-b. [b]AD significantly different from FTD-b. [c]Median of months between onset of symptoms—as reported by patient or his/her spouse to the primary care provider—and testing in the false-belief task. [d]Healthy elderly significantly different from AD. [e]Data from 1 AD patient and 3 FTD patients were unavailable for this task. [f]Data from 2 FTD-b patients were unavailable for these tasks.
*All comparisons at $p < .05$.

Tasks

Four standard false-belief tasks were used: (a) first-order change in location, (b) second-order change in location, (c) unexpected contents, and (d) appearance/reality.

First-order change-in-location task

In this task, a protagonist (e.g., Tom) places an object in one location (e.g., a toy in a box) and leaves the scene. While Tom is off the scene, a second character (e.g., Mary) moves the object to a new location (e.g., to a basket). When the first character returns, three questions are asked: a *false-belief* question (where will Tom look for the toy?), a *memory* question (where did Tom put the toy before he left the room?), and a *reality* question (where is the toy now?). Each patient completed three different stories, each story having a different set of characters, objects, and locations. The stories were acted out on video with voice-over narration. A video display is thought to have a distancing effect in that the target true location becomes less salient than when the story is enacted with real objects. This should reduce the inhibitory demands of the task, while keeping the conceptual demands unchanged (Astington & Baird, 2005a).

Second-order change-in-location task

In this modified version of the false-belief task, Tom peeks and, unbeknownst to Mary, watches her move the toy. Participants are asked to infer where Mary—who does not know that Tom was peeking—will think he will look for the toy. In addition to this *second-order false-belief* question (where does Mary think Tom will look for the toy?), participants were asked a *first-order false-belief* question (does Mary think that Tom can see her?) and two *story comprehension* questions (Can Tom see Mary? Where does Tom think the toy is?).

Each story was narrated by the experimenter and was illustrated by a sequence of three pictures. Each patient completed two different stories, each story having a different set of characters, objects, and locations.

Unexpected contents task

Participants were shown a familiar container (box of Smarties candy) and were asked what they thought was inside it. After they reported "candy," the experimenter revealed that the box actually contained Band-Aids. The Band-Aids were placed back inside the box, and the lid was closed. Participants were then asked (a) what a naïve observer, who hadn't seen inside the box, would think was inside it (*other* false-belief question), (b) what they themselves thought was inside the box before opening it (*self* false-belief question), and (c) what was really inside the box (control question).

Appearance–reality task

Participants were shown a yellow star and were asked to report its color. After they reported "yellow," the experimenter removed a yellow filter to reveal that the true color of the star was white. The experimenter covered the star with the filter again and asked three questions: (a) what color the star looked like (*appearance* question); (b) what color the star really was (*reality* question); and (c) what color the participant had thought the star was before the filter was removed (*false-belief* question).

Both the unexpected contents task and the appearance–reality task were first introduced in the developmental literature in an effort to reduce the cognitive demands of the false-belief task while retaining the conceptual requirements (e.g., Gopnik & Astington, 1988; Perner, Leekam, & Wimmer, 1987).

Design

Each patient completed a total of 8 first-order false-belief questions, 2 second-order false-belief questions, and 16 control questions for memory and story comprehension. Patients first completed the first-order false-belief tasks, after which they completed the second-order false-belief task. Normal controls only completed the second-order false-belief task (two trials), as normal adults are known to perform at ceiling on the first-order false-belief task.

To prevent contamination from errors in memory or story comprehension, only trials in which the control questions were answered correctly were included when computing first-order false-belief performance. Similarly, only trials in which the control questions and the first-order false-belief question were answered correctly were used in computing second-order false-belief performance. A total of 5 patients (4 AD, 1 FTD-b) failed to meet this criterion for the second-order false-belief stories and were excluded from that analysis. To assess theory-of-mind reasoning under conditions of low cognitive demand, we compared first-order false-belief accuracy between FTD-b and AD. To assess performance under conditions of high cognitive demand, we compared second-order false-belief performance between both patient groups and the healthy elderly, and between the two patient groups (FTD-b vs. AD).

RESULTS

Each patient answered a total of eight first-order false-belief questions.[3] For each patient, a percentage score was calculated, dividing the number of correct answers by the number of questions (e.g., 8/8 = 100%), as patients' performance did not vary across the eight questions, Cochran's $Q(7, 28) = 10.7$, *ns*. Next, the individual scores were averaged by group (see Table 2). The same approach was used to calculate the percentage scores of the control questions and the second-order false-belief questions.

The data for the false-belief tasks were not normally distributed, and therefore performance between groups was compared using nonparametric Mann–Whitney U tests.[4] These tests revealed no significant group differences in the first-order false-belief question, $U = 77$, $Z = -1.0$, *ns*, nor in the control questions, $U = 92$, $Z = -0.1$, *ns* . In fact, both patient groups performed near ceiling, and only 8 patients (4 in each group) scored less than perfect in the false-belief question. Did a cognitive deficit contribute to the less-than-perfect performance in these patients? To address this question, we compared the neuropsychological scores of patients who made at least one first-order false-belief error

[3]The eight questions assessing first-order false-belief reasoning were as follows: three stories of first-order change-in-location task, two questions for the unexpected contents task, one question for the appearance reality task, and two first-order false-belief questions embedded in the second-order change-in-location tasks.

[4]Although we report nonparametric statistics, it is worth pointing out that the same pattern of results was obtained when using t tests.

TABLE 2
Percentage accuracy data for the false-belief tasks

False-belief task	*Question*	*Healthy elderly*	*AD*	*FTD*
First-order	False-belief	n/a	95.8 (11)	93.4 (10)
	Control	n/a	97.1 (7)	98.5 (4)
Second-order[a]	False-belief	91.6 (19)	69.2 (38)	70.0 (42)
	Control	97.9 (7)	92.3 (12)	90.0 (17)

Note. AD = Alzheimer's disease. FTD = frontotemporal dementia. Standard deviations in parentheses.
[a]Data from 1 FTD-b and 4 AD patients who failed control questions in both second-order false-belief stories were excluded because false-belief performance in such cases is uninterpretable.

to those of patients who were flawless. In many cognitive domains, *t* tests revealed significant differences between these two groups. Patients who made errors in the first-order false-belief question performed significantly worse in the Dementia Rating Scale (DRS), the comprehension section of the Western Aphasia Battery, the digit span tasks, the Boston Naming Task, semantic fluency task, line orientation task, and Rey copy figure (*p*s < .05). These results point to a contribution of cognitive deficits in impaired false-belief performance.

To further test the contribution of cognitive resources to theory-of-mind reasoning, we looked at performance in the second-order false-belief task. The cognitive deficit hypothesis predicted impaired performance in both patient groups. In support of this cognitive account, patients (10 FTD, 13 AD) were impaired in second-order false-belief reasoning relative to the healthy elderly group, U (33) = 91, $Z = -1.9$, $p < .05$, but there was no significant difference between FTD-b and AD, U (21) = 63, $Z = -0.1$, *ns*.

DISCUSSION

The present study explored false-belief understanding in FTD-b and found no evidence of specific impairment. Patients with FTD-b and patients with AD performed equally well in the first-order false-belief tasks, reaching ceiling performance. Performance in second-order false-belief tasks was similarly impaired for both patient groups. These results suggest that FTD-b's performance in false-belief tasks depends primarily on the cognitive demands of the task.

The results pose a challenge to the claim that FTD-b's deficit in theory-of-mind reasoning is due to a conceptual deficit in mentalizing. The tasks we chose for our first-order false-belief battery were among those that, according to the developmental literature, pose least cognitive effort. It is important to emphasize that, notwithstanding these differences in cognitive demands, the conceptual requirements remain the same across all versions of the first-order false-belief task. In other words, all versions require a similar understanding of the mind as a representational system and of beliefs as causally effective in people's behavior. This mentalizing ability seems spared in early stages of FTD-b, at least as assessed by the first-order false-belief task.

Unlike our study, Gregory et al. (2002) found FTD-b patients to be impaired in the first-order false-belief reasoning relative to patients with AD. Both studies used similar criteria for selecting patients that yielded similar neuropsychological profiles. Some main differences were the patients' premorbid IQ, as measured by the National Adult Reading Test (NART), and their years of education. In our study, patient groups were matched on these measures; in Gregory's study, the FTD-b group had lower premorbid IQ and fewer years of education than their AD group. However, findings for the first-order task remained significant in Gregory's study even after including years of education as a covariate.

The two studies also differed on the specific tasks used to assess first-order false belief. In the study by Gregory and collaborators (2002), first-order false-belief performance was assessed with four trials of the change-in-location tasks. In our study, we used a variety of first-order false-belief tasks. Although such variety aimed to minimize the superficial similarities across tasks, we can think of no obvious reason why FTD-b patients should benefit from such variety. Also, FTD-b patients in our study performed as well in the change-in-location tasks as in any of the other first-order tasks. Thus, it seems unlikely that these changes could account for the difference in results.

Other methodological differences exist between the two studies. In Gregory et al.'s (2002) study, the story pictures were displayed and narrated by the experimenter. In our study, the change-in-location stories were acted out on video by two child actors, with adult voice-over narration. Videotape presentation removes any experimenter's bias in narration. It also allows participants to see the whole event unfolding, instead of having to recreate it from a series of pictures. Finally, it is possible that we failed to replicate the first-order false-belief impairment because there is not such impairment in the FTD-b population (i.e., a Type I error). The probability of committing a Type I error grows larger when the comparison includes groups that perform near ceiling and thus have low within-group variability, as was the case in Gregory's study for healthy adults and AD patients performing the first-order task.

Previous studies have proposed that FTD-b's social impairment stems from a deficit in theory-of-mind reasoning (Gregory et al., 2002). Although we found no support for this hypothesis, it remains an open question whether more sensitive measures of false-belief reasoning may reveal subtle deficits (Birch & Bloom, 2007). Alternatively, FTD-b's social deficits may stem from an inability to integrate mental reasoning with emotional processing. Evidence for this alternative hypothesis comes from FTD-b's impairment in *faux pas* understanding (Gregory et al., 2002; Torralva et al., 2007). The faux pas task requires detecting that something hurtful or socially inappropriate has been said unintentionally. Thus, detecting a faux pas requires a mental-state attribution (i.e., the speaker does not know the statement will be hurtful and therefore is not intending to harm feelings), and in this sense the task is similar to the false-belief task. However, unlike the false-belief task, the faux pas task further requires an understanding of the emotional content of the statement (i.e., it is hurtful). This makes the faux pas a more complex task that requires both affective understanding and the integration of contextual information. Indeed, FTD-b patients are impaired in affective processing as well as in the integration of information (Morrison et al., 2004; Rahman et al., 1999). FTD-b patients are also impaired in the recognition of some facial emotions, which can contribute to the poor social skills (Fernandez-Duque & Black, 2005; Keane, Calder, Hodges, & Young, 2002; Lavenu, Pasquier, Lebert, Petit, & Van der Linden, 1999; Rosen et al., 2002).

Both FTD-b and AD groups were impaired in the second-order false-belief task, a result that replicates those of Gregory et al. (2002). However, success on the second-order false-belief task depends on many cognitive abilities. Developmental studies show that the age at which normally developing children pass the second-order false-belief task varies dramatically depending on the cognitive demands of the task (Coull et al., 2006; Sullivan et al., 1994). Studies on AD patients reveal impaired performance even when mentalizing is not required, as in the case of the "false" photograph task (Zaitchik, Koff, Brownell, Winner, & Albert, 2006). Deficits in reasoning, language comprehension, working memory, inhibition, or pragmatics could lead to impaired performance. There is substantial evidence that patients with FTD-b have deficits in all these domains, as do patients with AD (Morrison et al., 2004; Price, Davis, Moore, Campea, & Grossman, 2001; Rhee et al., 2001).

In cognitive development research, the term "theory of mind" is often narrowly defined to refer to the conceptual understanding of the mind as a representational system that causally influences behavior. In contrast, in neuropsychology the term has often been used in a broader sense to refer to the ability to successfully navigate the social world, including complex abilities such as empathy, irony, moral judgment, and deception (Stuss, Gallup, & Alexander, 2001). There is no dispute that, under this umbrella definition, the "theory-of-mind" abilities of FTD-b patients are impaired (Kipps & Hodges, 2007; Lough et al., 2006; Torralva et al., 2007). After all, that is the main inclusion criterion for the clinical definition of FTD-b. However, few researchers would dare to propose that "theory of mind" thus defined is independent from general cognitive processes, or claim a direct link between theory of mind thus conceptualized and discrete brain structures. The more interesting and contentious claim is that there is a specific deficit in understanding the mind as a representational system, which is at the core of certain brain pathologies such as FTD-b. For this more provocative claim, we found no supporting evidence.

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