Theory of mind impairments in patients with semantic dementia

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Semantic dementia is characterized by semantic deficits and behavioural abnormalities that occur in the wake of bilateral inferolateral and predominantly left-sided anterior temporal lobe atrophy. The temporal poles have been shown to be involved in theory of mind, namely the ability to ascribe cognitive and affective mental states to others that regulates social interactions by predicting and interpreting human behaviour. However, very few studies have examined theory of mind in semantic dementia. In this study, we investigated both cognitive and affective theory of mind in a group of patients with semantic dementia, using separate objective and subjective assessment tasks. Results provided objective evidence of an impact of semantic dementia on cognitive and affective theory of mind, consistent with the patients’ atrophy in the left temporal lobe and hypometabolism in the temporal lobes and the medial frontal cortex. However, the subjective assessment of theory of mind suggested that awareness of the affective but not cognitive theory of mind deficit persists into the moderate stage of the disease.

Keywords: semantic dementia; cognitive/affective theory of mind; objective/subjective assessment; imaging
Abbreviations: FTD = frontotemporal dementia

Introduction

Semantic dementia is the term that was proposed by Snowden et al. (1989) to designate patients suffering from a progressive neurodegenerative disorder characterized by a ‘loss of semantic information’. From a cognitive point of view, patients start to display multimodal semantic memory deterioration, manifested in specific language disturbances, in the early stages of semantic dementia. Spontaneous speech is fluent but empty, with preserved phonological and grammatical aspects as well as repetition, while naming and comprehension gradually become impaired. These symptoms are generally accompanied by semantic paraphasias, agnosia for objects and prosopagnosia, but visuospatial skills and day-to-day memory are relatively preserved (Hodges and Patterson, 2007). From a nosological perspective, semantic dementia, also known as the temporal variant of frontotemporal dementia...
dementia (FTD), is one of the three clinical forms of frontotemporal lobar degeneration, along with the frontal or behavioural variant and progressive non-fluent aphasia (Neary et al., 1998). Frontotemporal lobar degeneration is a neurodegenerative process affecting the frontal and/or temporal lobes. Its clinical picture includes aberrations not only in language and cognition, but also in behaviour and social function (for a review, see Wittenberg et al., 2008). For instance, loss of empathy and impaired emotion recognition are some of the main symptoms (Snowden et al., 2001; Lough et al., 2006).

Personality modifications and social dysfunctions in the behavioural variant of FTD are assumed to be related to theory of mind impairments (Kipp and Hodges, 2006). Theory of mind is the ability to infer people’s mental states (Premack and Woodruff, 1978; Frith and Frith, 1999). It allows individuals both to ascribe cognitive and affective states to others and to deduce their intentions from their attitudes (Brothers and Ring, 1992; Coricelli, 2005). Insofar as theory of mind enables individuals to predict, anticipate and interpret human behaviour, it is essential for regulating social interactions (Beer and Ochsner, 2006). A distinction can be made between cognitive theory of mind, which concerns the cognitive states, beliefs, thoughts or intentions of other people (Brothers and Ring, 1992; Coricelli, 2005), and affective theory of mind, which concerns the affective states, emotions or feelings of others (Brothers and Ring, 1992).

Furthermore, studies (Baron-Cohen et al., 1997; Adolphs et al., 2002) have found that basic and complex emotions are differently addressed: while ‘basic emotions’ are automatically and cross-culturally recognized, and probably rely on an innate mechanism (Izard, 1994), ‘complex emotions’ express blends of mental states or social emotions that generally arise within an interpersonal context. Although some researchers hold that affective theory of mind is similar to empathy (Decety and Lamm, 2006), these two concepts are actually somewhat different. While both conduct to the genuine understanding of mental affective states, we consider that the term ‘empathy’ refers to the feeling and experiencing of another person’s emotion, whereas affective theory of mind refers to the ability to adopt the other person’s point of view, or ‘put oneself in his/her shoes’, without necessarily experiencing any emotion (Pacherie, 2004). That said, some theoretical conceptions of empathy distinguish between the ‘emotional empathy’ described above and ‘cognitive empathy’, which is synonymous with affective theory of mind (Davis, 1980; Eslinger, 1998; Shamay-Tsoory et al., 2004). In addition to the cognitive/affective theory of mind distinction, we can distinguish between first- and second-order mental representations. ‘First-order’ refers to representations of an individual’s thoughts that are achieved by adopting the latter’s perspective (e.g. ‘I think that Mr X thinks that . . .’). ‘Second-order’ representations, which can be likened to ‘meta-representations’ (Morin, 2006, 2010), involve simultaneously adopting two perspectives (e.g. ‘Mr X thinks that Miss Y thinks that . . .’).

Numerous neuroimaging studies have investigated the neural correlates of theory of mind via different theory of mind tasks, such as inferring characters’ cognitive mental states through verbal or visual stories (Brunet et al., 2000; Walter et al., 2004), inferring affective states from photographs of emotional faces or the eye region (Baron-Cohen et al., 1999, 2001), observing the movements and interactions of geometrical shapes (Schultz et al., 2003; Gobbini et al., 2007), and other subject–agent interaction procedures (Gallagher et al., 2002; Schilbach et al., 2006). These studies have highlighted a theory of mind-related cerebral network (for reviews, see Abu-Akel, 2003; Frith and Frith, 2003; Carrington and Bailey, 2009) that is broadly constituted by the prefrontal cortex, including the orbital and medial prefrontal cortices (Baron-Cohen and Goodhart, 1994; Fletcher et al., 1995; Goel et al., 1995; Gallagher et al., 2000; Happanen et al., 2004; Adenzato et al., 2010), the temporal lobes, including the superior temporal sulci and the temporal poles (Olson et al., 2007), and the amygdala (Baron-Cohen et al., 1999). While less attention has been paid to the temporal poles than the prefrontal cortex in theory of mind, Ross and Olson (2010) recently drew attention to the contribution of the anterior temporal lobes in social attribution and theory of mind tasks. Their findings, in healthy adults, underline the fact that theory of mind abilities rely on the anterior temporal lobes to activate a set of social semantic representations. In other words, a body of social semantic knowledge stored in the anterior temporal lobes is required in order to understand other people’s mental states.

The profound semantic deterioration seen in patients with semantic dementia is generally the result of bilateral atrophy of the temporal lobes. Neuroimaging studies in patients with semantic dementia have indicated an anteroposterior gradient, with greater atrophy anteriorly. Moreover, this atrophy tends to be predominantly left-sided, rather than right-sided or symmetrical (Gorno-Tempini et al., 2004; Desgranges et al., 2007; Wittenberg, 2008). Otherwise, authors have reported significant hypometabolism in the whole left temporal cortex and in the right temporal pole. More extensive than the atrophy, this hypometabolism also encompasses the frontal areas (Edward-Lee et al., 1997) especially the bilateral orbitofrontal cortex (Desgranges et al., 2007).

In light of the cognitive and cerebral impairments in semantic dementia, it is legitimate to ask whether theory of mind is normal in patients with semantic dementia. Surprisingly little is known about this issue, whereas theory of mind has been widely studied in the behavioural variant of FTD (for a review, see Adenzato et al., 2010). Some authors have, however, assessed empathy in semantic dementia via different scales, such as the Interpersonal Reactivity Index (Davis, 1983). They have generally found that patients with semantic dementia have impairments in both the cognitive and emotional components of empathy. This decline has been related to right-sided temporal atrophy (Perry et al., 2001; Rankin et al., 2005). However, in a recent case report, Calabria et al. (2009) showed that the ‘cognitive’ component of empathy is more impaired than the ‘emotional’ one in the presence of left-sided temporal atrophy. Their finding suggests that the cognitive aspects of empathy (and, by extension, of affective theory of mind) are sustained by the left temporal lobe. As far as theory of mind per se is concerned, Eslinger and colleagues (2007) studied cognitive theory of mind in a group of 14 patients, some of whom had semantic dementia. Using cognitive theory of mind tasks that elicited either intention-based predictions or first- and second-order beliefs of characters in a social context they demonstrated impairment in both tasks. This impairment was less severe.
than that found in a group of patients suffering from the behavioural variant of FTD. However, one major limitation to this study was that patients with semantic dementia were mixed with patients with non-fluent progressive aphasia, without giving any indication as to either the number and characteristics of the patients with semantic dementia, or their specific performances. Adopting a different approach, Rankin et al. (2009) studied sarcasm and whether it could be detected from paralinguistic cues in several groups of patients with neurodegenerative diseases, including a group of 11 patients with semantic dementia. Like irony, sarcasm is a high-level communicative intention requiring cognitive theory of mind (Sabbagh et al., 2004). The authors found that independently of their language deficit, patients with semantic dementia failed to detect sarcasm in non-verbal features, whereas they outperformed controls in the innuendo-free condition. These findings suggest that the cognitive aspects of theory of mind tend to deteriorate in semantic dementia, although the study used only one cognitive theory of mind task and did not explore affective theory of mind. That said, in a previous exploratory investigation of a single case with semantic dementia, we found deficits in cognitive theory of mind in the absence of deficits in affective theory of mind (Bon et al., 2009).

The aim of the present study was to examine theory of mind abilities in semantic dementia by investigating for the very first time both the cognitive and affective dimensions of theory of mind in the same group of patients with semantic dementia. Using the thorough theory of mind assessment validated by Duval et al. (2011), we carried out not just an objective theory of mind assessment but a subjective one, too. The objective assessment comprised specially adapted standard tests evaluating either cognitive or affective theory of mind, plus an original composite test covering both these aspects, that was designed to explore theory of mind under conditions matching the social context of everyday life. In the subjective assessment, a self-rating theory of mind scale was used to probe theory of mind deficit awareness.

In light of the cognitive and cerebral deterioration in semantic dementia and the scant data available in the literature, we expected to find impairment of cognitive theory of mind in patients with semantic dementia involving the inference of intentions and high-level beliefs, as well as of affective theory of mind involving the inference of emotions.

### Materials and methods

#### Patients with semantic dementia

We studied 15 patients (six males, nine females) in the early to moderate stages of semantic dementia (mean age = 64.27 ± 6.53 years, range: 51–78 years; mean disease duration = 3.93 ± 1.98 years), who were selected on the basis of research criteria for semantic dementia established by Neary et al. (1998). Demographic data are detailed in Table 1. The selection of patients was carried out according to a codified procedure in French expert centres (University hospitals of Caen and Rennes) by senior neurologists whose main activity consists of the diagnosis and follow-up of patients suffering from neurodegenerative disorders, as well as by neuropsychologists and speech therapists. Patients with a history of alcoholism, head trauma, neurological or psychiatric illness were excluded. In all patients, according to their families, the predominant and inaugural symptom had been a semantic memory deficit, reflected by anoma and word comprehension difficulties, as well as by deficits in the recognition of familiar people. With the exception of one patient who had additional day-to-day memory impairment, in each case, the family reported preserved everyday memory and autonomy. Therefore, these patients could continue to carry out everyday activities such as doing their own shopping, using public transport, keeping general practitioner’s appointments and remembering recent or current events. They were also well oriented in time and space. For each patient, cognitive complaints and levels of depression were measured via the short Cognitive Difficulties Scale (McNair and Kahn, 1983) and the short Geriatric Depression Scale (Yesavage et al., 1983), respectively. There was no significant difference with healthy subjects. Their overall cognitive efficiency was assessed using the Mattis Dementia Rating Scale (Mattis, 1976). All patients displayed overall cognitive decline (Table 1).

Furthermore, 10 patients underwent a high-resolution T1-weighted volume MRI scan (3T scanner) and nine of them a resting PET investigation using [18F]fluoro-2-deoxy-D-glucose at the CYCERON centre (Caen, France). For both types of imaging data, we assessed group differences in SPM5 (Statistical Parametric Mapping) using a threshold of P = 0.01 family-wise error-corrected, to obtain maps of significant atrophy and hypometabolism in patients with semantic dementia compared with an independent sample of 26 control adults, paired in age and years of education, from our imaging database. The remaining patients underwent a standard MRI scan, which confirmed the diagnosis. This mainly revealed atrophy of the temporal neocortex, predominantly in the left hemisphere in all cases but one.

For the 10 above mentioned patients, our SPM analysis showed that regions of significant grey matter loss involved the whole temporal neocortex (temporal pole and inferior, middle and superior temporal gyri), extending to the hippocampal region (hippocampus, parahippocampal gyrus, amygdala), as well as the fusiform gyrus, insula and caudate nucleus (Fig. 1A). Although present bilaterally, the atrophy predominated in the left hemisphere, especially for posterior and superior temporal regions. Regions of significant hypometabolism roughly overlapped the significant grey matter loss (Fig. 1B). On the left side, it encompassed the entire temporal lobe, including both the whole temporal neocortex and the hippocampal region, and also encroached on the fusiform gyrus, insula, caudate and pallidum.

### Table 1 General data about the patients with semantic dementia and healthy controls groups

<table>
<thead>
<tr>
<th></th>
<th>Patients with semantic dementia (n = 15)</th>
<th>Healthy controls (n = 36)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male/female)</td>
<td>6/9</td>
<td>12/24</td>
</tr>
<tr>
<td>Age (years)</td>
<td>64.27 ± 6.53</td>
<td>64.14 ± 8.25</td>
</tr>
<tr>
<td>Education (years)</td>
<td>11.02 ± 4.07</td>
<td>11.69 ± 3.91</td>
</tr>
<tr>
<td>sCDSa</td>
<td>24.15 ± 9.41</td>
<td>19.81 ± 9.99</td>
</tr>
<tr>
<td>sGDSb</td>
<td>1.15 ± 1.34</td>
<td>0.72 ± 0.74</td>
</tr>
<tr>
<td>Mattisc</td>
<td>118 ± 9.57</td>
<td>139.05 ± 4.38</td>
</tr>
<tr>
<td>Illness duration (years)</td>
<td>3.93 ± 1.98</td>
<td></td>
</tr>
</tbody>
</table>

a Administered to 13 patients with semantic dementia. The cut-off score is 30.
b Administered to 13 patients with semantic dementia. The cut-off score is 2.
c Administered to 12 patients with semantic dementia and solely to participants over 65 years. The cut-off score is 130.

sCDS = short Cognitive Difficulties Scale; sGDS = short Geriatric Depression Scale.
nucleus. On the right side, the hypometabolism was less significant and mainly concerned the temporal pole and medial temporal region (including the amygdala and parahippocampal gyrus). Frontal regions, especially the bilateral medial orbitofrontal cortex and rectus gyrus, as well as the left anterior cingulate cortex, were also involved, albeit to a lesser extent.

This protocol was approved by the Regional Ethics Committee. Controls and patients gave written consent to the procedure prior to the investigation.

**General neuropsychological assessment**

In order to gain a clear picture of their neuropsychological disturbance, the patients with semantic dementia underwent a general neuropsychological assessment beforehand (mean: 5.3 ± 2.76 months prior to inclusion in the study), comprising semantic, episodic and working memory tests. Neuropsychological test performances for the group of patients with semantic dementia are summarized in Table 2. We explored semantic memory by means of: (i) the Concept subscale of the Mattis scale (Mattis, 1976); (ii) literal and categorical verbal fluency tasks in 2 min each (Cardebat et al., 1990); and (iii) picture naming tasks (DO80, Deloche and Hannequin, 1997; or BECS-GRECO naming, Belliard et al., 2008). We assessed verbal episodic memory using the Logical Memory subtest of the Wechsler Memory Scale (Wechsler, 2001), while visuospatial episodic memory was probed with the ‘Test de la Ruche’ (Violon and Wijns, 1984) and/or the delayed recall of the Rey–Osterrieth complex figure (from Lezak, 1995). Working memory was evaluated by means of a digit span test (Wechsler, 2001). To assess executive functions, as defined by Miyake et al. (2000), we investigated the shifting process, updating function and inhibition of inappropriate responses using the Trail-Making Test (Reitan, 1958), the running span task (Quinette et al., 2003) and the Stroop Test (Stroop, 1935), respectively, while problem-solving was evaluated by means of Raven’s coloured progressive matrices (Raven, 1965). Finally, visuoconstructive abilities were probed with the copy of the Rey–Osterrieth Complex Figure (Lezak, 1995).

In brief, the results reported in Table 2, clearly indicated that the patients with semantic dementia displayed massive semantic memory difficulties, with anoma and impoverished general semantic knowledge of concepts. While visual episodic memory was relatively preserved, verbal episodic memory was impaired, although this may have been accentuated by interference with semantic and language disorders. However, these deficits were probably not enough to explain the poor memory performances, suggesting genuine deficits of episodic memory, in accordance with abnormalities in the hippocampal region and previous findings both by our group (Desgranges et al., 2007) and by others (Chan et al., 2001; Good et al., 2002; Nestor et al., 2006). Similarly, executive functions appeared preserved in most of the patients, and no deficits were found in visuoconstructive abilities.

**Theory of mind assessment**

In order to perform consistent and exhaustive measures of theory of mind within the group of patients with semantic dementia, we administered a series of assessment tasks taken from Duval et al. (2011) that were designed to probe both the cognitive and affective dimensions of theory of mind. More specifically, we conducted an objective assessment of theory of mind by means of classic visual and verbal tasks, adapting them in order to reduce cognitive load. Cognitive theory of mind was assessed by an attribution of intention test (Brunet et al., 2000) and a false-belief task (Wimmer and Perner, 1983), and affective theory of mind via a version of the Reading the Mind in the Eyes Test (Baron-Cohen et al., 1997). We also added a composite task called ‘Tom’s taste’, which we developed to give a better account of this ability. Furthermore, an original self-rating questionnaire was used to assess awareness of the putative theory of mind deficit. We checked that participants fully understood each theory of mind task and, where necessary, provided an aid, mainly in the form of a glossary or the rewording of sentences. If their understanding remained impaired, the test was not performed.

The performances of patients with semantic dementia were compared with those obtained in 36 healthy age-matched controls recruited from a local panel of volunteers (Duval et al., 2011). Each one gave his/her informed consent to the experimental procedure. Their inclusion was based on the absence of neurological or psychiatric medical history reported on a health questionnaire, signs of depression.
as measured on the short Geriatric Depression Scale, and memory complaints, as measured on the short Cognitive Difficulties Scale. Moreover, adults over 65 years old were screened for dementia using the Mattis Dementia Rating Scale. We also checked executive functioning with the Trail Making Test (mental flexibility) and the Stroop test (inhibition). All participants’ scores were within the norm (data not shown).

### Objective theory of mind assessment

#### Attribution of intention task

This visual attribution of intention task was derived from Brunet et al. (2000). It consisted of a set of 30 short comic strips, selected from 88 comics. Each of them comprised three pictures illustrating a scenario. The aim was to find the most logical conclusion for each scenario by choosing a fourth picture among three others. The comic strips were divided into three conditions. In the first, 10 stories required participants to draw inferences from a character’s actions (theory of mind condition). In the second, 10 stories showed a character without any intention (control condition with characters), while in the third, 10 scenarios were based on the physical properties of objects (control condition with object). The latter two formed a control condition. Scores were percentages of correct responses in each condition.

#### False-belief task

The false-belief task, an original visual-and-verbal task, was based on false-belief cartoon tasks such as ‘Sally and Ann’ (Wimmer and Perner, 1983). It was made up of 15 short comic strips illustrating scenarios that were developed within our laboratory (Bon et al., 2009). Each comic strip comprised three pictures with a short written description (for an example, see Fig. 2). The aim was to understand the story by reading the scenario, and then answer a question with two possible responses. There were two conditions: in the theory of mind condition, the question was about the belief of one of the characters in the story. Eight of the 15 cartoons involved first-order representations (‘X thinks that...’) and seven second-order ones (‘X thinks that Y thinks that...’). In the control condition, the same cartoons were used, but the question probed participants’ understanding of the reality of the cartoon scenario. In order to reduce cognitive load, the pictures and written descriptions remained visible throughout. We inserted an

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### Table 2 Neuropsychological data of the semantic dementia patient group

<table>
<thead>
<tr>
<th>Cognitive tests</th>
<th>n</th>
<th>m ± s</th>
<th>z-score</th>
<th>%impaired semantic dementia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semantic memory</strong></td>
<td></td>
<td></td>
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<tr>
<td>Literal (‘P’) fluency</td>
<td>12</td>
<td>12.33 (±4.44)</td>
<td>-1.8 (±0.71)</td>
<td>66.67</td>
</tr>
<tr>
<td>Categorical (animals) fluency</td>
<td>12</td>
<td>9.25 (±3.08)</td>
<td>-2.86 (±0.35)</td>
<td>100</td>
</tr>
<tr>
<td>Picture naming (%)</td>
<td>15</td>
<td>39.97 (±25.06)</td>
<td>-15.64 (±7.53)</td>
<td>100</td>
</tr>
<tr>
<td>Concept (Mattis) (/39)</td>
<td>15</td>
<td>32.4 (±3.07)</td>
<td>-</td>
<td>33.33</td>
</tr>
<tr>
<td><strong>Episodic memory</strong></td>
<td></td>
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<tr>
<td>Logical memory</td>
<td></td>
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<tr>
<td>Immediate recall (/75)</td>
<td>10</td>
<td>22.2 (±10.32)</td>
<td>-1.8 (±1.23)</td>
<td>50</td>
</tr>
<tr>
<td>Delayed recall (/50)</td>
<td>10</td>
<td>12.5 (±7.44)</td>
<td>-1.66 (±1.12)</td>
<td>40</td>
</tr>
<tr>
<td>Recognition (/50)</td>
<td>10</td>
<td>16.5 (±7.92)</td>
<td>-2.21 (±2.21)</td>
<td>30</td>
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<tr>
<td>Test de la Ruche</td>
<td></td>
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</tr>
<tr>
<td>Immediate recall (/10)</td>
<td>11</td>
<td>9.09 (±2.21)</td>
<td>0.29 (±1.22)</td>
<td>9.09</td>
</tr>
<tr>
<td>Delayed recall (/10)</td>
<td>10</td>
<td>9.2 (±1.62)</td>
<td>0.66 (±0.7)</td>
<td>0</td>
</tr>
<tr>
<td>Recognition (/10)</td>
<td>10</td>
<td>10</td>
<td>0.55 (±0.22)</td>
<td>0</td>
</tr>
<tr>
<td>Rey–Osterrieth complex figure</td>
<td></td>
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<tr>
<td>Delayed recall (/36)</td>
<td>13</td>
<td>14.54 (±8.31)</td>
<td>-0.64 (±1.53)</td>
<td>15.38</td>
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<tr>
<td><strong>Working memory</strong></td>
<td></td>
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<tr>
<td>Forward digit span</td>
<td>15</td>
<td>5.8 (±1.32)</td>
<td>0.12 (±1.23)</td>
<td>0</td>
</tr>
<tr>
<td>Backward digit span</td>
<td>15</td>
<td>4.2 (±1.47)</td>
<td>0.22 (±1.43)</td>
<td>13.33</td>
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<tr>
<td><strong>Executive functions</strong></td>
<td></td>
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<tr>
<td>Attention</td>
<td></td>
<td></td>
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<tr>
<td>Trail-Making Test A (s)</td>
<td>15</td>
<td>52.93 (±14.05)</td>
<td>0.69 (±1.00)</td>
<td>20</td>
</tr>
<tr>
<td>Errors</td>
<td></td>
<td>0.07 (±0.26)</td>
<td>-</td>
<td>6.67</td>
</tr>
<tr>
<td>Shifting</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Trail-Making Test B (s)</td>
<td>14</td>
<td>110.29 (±33.23)</td>
<td>0.04 (±0.58)</td>
<td>6.67</td>
</tr>
<tr>
<td>Errors</td>
<td></td>
<td>0.33 (±0.82)</td>
<td>-</td>
<td>13.33</td>
</tr>
<tr>
<td>Trail-Making Test B-A (s)</td>
<td>14</td>
<td>59.36 (±30.74)</td>
<td>-0.11 (±0.61)</td>
<td>6.67</td>
</tr>
<tr>
<td>Updating</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Running span (/16)</td>
<td>11</td>
<td>5.27 (±3.72)</td>
<td>-0.98 (±1.19)</td>
<td>27.27</td>
</tr>
<tr>
<td>Inhibition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colour Stroop Test (interference in s)</td>
<td>14</td>
<td>162.57 (±54.08)</td>
<td>0.75 (±1.13)</td>
<td>21.43</td>
</tr>
<tr>
<td>Non-verbal reasoning</td>
<td></td>
<td></td>
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<tr>
<td>Raven’s coloured progressive matrices (/36)</td>
<td>12</td>
<td>32.25 (±4.39)</td>
<td>0.74 (±0.93)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Instrumental functions</strong></td>
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<tr>
<td>Praxis</td>
<td></td>
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<tr>
<td>Copy of Rey–Osterrieth complex figure (/36)</td>
<td>15</td>
<td>34.87 (±1.96)</td>
<td>0.19 (±0.81)</td>
<td>0</td>
</tr>
</tbody>
</table>

n = number of patients with semantic dementia for the task considered; z-score = mean of z-scores of patients with semantic dementia.
interference task (classic digit span task) between the first-and
second-order cartoons and between the theory of mind and control
conditions. Each performance was expressed as a percentage of
correct responses for each condition.

Eyes test

The Eyes test was inspired by the test devised by Baron-Cohen et al.
(1997). It consisted of 20 black-and-white photographs of the eye
region of a female actor who was asked to produce different facial
expressions. Ten of the photographs depicted ‘basic emotions’
(i.e. happiness, surprise, sadness, anger and fear) and 10 ‘complex
emotions’ [i.e. guilt, thoughtful, flirting, scheming, puzzled, interested
twice), quizzes, arrogant and bored]. Under each picture, three
adjectives (one target and two foils) described basic or complex emo-
tions. Participants were asked to identify which adjective best
described the person’s mental state. This test allowed us to measure
emotion recognition in the basic emotions condition and affective
theory of mind in the complex emotions one. We took the view
that affective theory of mind abilities are closely related to the recog-
nition of complex mental emotions. Basic emotions are automatically
processed, can occur outside a social context and consequently
depend on a simple emotion recognition process. In contrast, complex
emotions generally involve an actual or imagined social object,
which could be another individual or a socially constructed self and
hence need to be inferred (Harel and Parkinson, 2008). They there-
fore require thinking and reasoning processes. Accordingly, we cal-
culated the percentage of correct responses for basic emotions (control
condition) and the percentage of correct responses for complex emo-
tions (theory of mind condition); the correct responses came from a
previous study in healthy subjects (Duval et al., 2011). A glossary had
been made available to the patients with semantic dementia so that
they would attend to the adjectives’ meaning.

Tom’s taste

Tom’s taste, an original task taken from Duval et al. (2011) and dis-
tantly inspired by Snowden et al. (2003), assessed the ability to judge
the preference of another person in a given context, based on the
content of his or her thoughts. The material consisted of 16 cartoon
drawings on separate sheets, each showing the centrally positioned
face of a character called Tom. This face either smiled or pouted, in
order to express Tom’s preference (i.e. affective theory of mind
aspect). Tom’s gaze was directed towards a balloon containing the
picture of an object (e.g. biscuits) to illustrate the content of Tom’s
thoughts (i.e. cognitive theory of mind aspect) meaning, for example,
that he likes biscuits. In the theory of mind condition, when the car-
toon was shown to the participant, the experimenter orally described a
short scenario to put it in context (e.g. ‘imagine that you’ve kindly
invited Tom to your house for tea or coffee. What would you serve
with the tea or coffee?’). The experimenter then showed four pos-
sible response pictures, chosen for their degree of relevance: mad-
elines (correct response, taking both Tom’s preference and the
context into account); chocolates (response taking the context into
account but not Tom’s preference); salted crackers (response taking
Tom’s preference into account but not the context); and oysters (un-
suitable response taking neither Tom’s preference nor the context into
account). Afterwards, participants were asked to justify their choice for
each item. Justifications were classified into four types: (i) P: justified
according to Tom’s preference; (ii) C: justified according to the con-
text; (iii) Self: justified according to participant’s own preference in
the context; and (iv) Other: any other justifications. A total score
was calculated for each type. Finally, in a last condition, we pre-
sented just the character’s face and thought (i.e. without the four
response pictures), and asked the participant what he/she could
deduce about the character’s tastes (e.g. ‘Tom likes biscuits’). In this
‘control-like condition’, we checked whether the test had been prop-
erly understood. In other words, we made sure that the patients’ basic
inferences (i.e. symbolic significance of the expressive face and the thought balloon) were accurate. Patients were excluded from the analysis if they failed on more than 50% of the items, a clear sign of their incomprehension. A total success score (%) was calculated for each condition.

**Subjective theory of mind assessment**

**Theory of mind scale**

This instrument consisted of 10 positive or negative sentences divided into two five-item subscales, with items drawn from several questionnaires, including Davis’ (1983) Interpersonal Reactivity Index, and subscales of the Eysenck Personality Questionnaire (Eysenck and Eysenck, 1985). It described various types of relationship one might have with others, eliciting either cognitive (thoughts, attitudes, behaviour) or affective (emotions, feelings) perspective taking. Thus, the cognitive theory of mind subscale assessed the ability to understand, infer or interpret the cognitive mental states of others (e.g. ‘I can easily deduce someone’s intentions’), while the affective theory of mind subscale measured the ability to infer or understand the feelings of others, or to act in response to emotions observed in other people (e.g. ‘I can easily identify the emotions that a person is experiencing’). Participants rated each item on a 4-point Likert-type scale ranging from 1 (‘Does not describe me at all!’) to 4 (‘Describes me completely’). A total score (subjective theory of mind measure) and two subscores (cognitive/affective theory of mind) were calculated and expressed as percentages, with higher scores associated with greater theory of mind abilities. To facilitate the use of this scale with the patients with semantic dementia, its mode of administration was modified: each item was read aloud by the examiner and the patient simply had to point to his/her response on a 4-point scale printed on a separate sheet. Task instructions were repeated and two rewritings of each item were provided, if necessary. However, if a patient nonetheless misunderstood one or two items, his/her score was calculated from the number of remaining items; if he/she misunderstood three items or more, he/she was excluded from the analysis of this task.

**Statistical analysis**

Given the sample size of the patient group, non-parametric analyses were used to measure internal consistency. The Mann–Whitney U-test was conducted to gauge intergroup differences and Wilcoxon pairwise comparisons to assess the effect of the experimental condition compared with the control one. For the purposes of these analyses, a unilateral statistical level of significance was set at 0.05. Statistical analyses were conducted with all the patients. However, when a patient totally failed to perform the task due to a profound comprehension deficit, he/she was excluded from the analysis for that particular task. These instances are indicated in Table 3, which shows the performances of the patients with semantic dementia and healthy controls on all the theory of mind tasks in each condition (theory of mind versus control). Finally, in order to better understand theory of mind performance in patients with semantic dementia, we also performed Spearman correlations between their neuropsychological scores and the theory of mind scores.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Comparison between patients with semantic dementia and healthy controls on theory of mind abilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>ToM tests and measures</td>
<td>Patients with semantic dementia (%)</td>
</tr>
<tr>
<td><strong>Objective assessment</strong></td>
<td></td>
</tr>
<tr>
<td>Cognitive theory of mind</td>
<td></td>
</tr>
<tr>
<td>Attribution of intention task*</td>
<td>72.86 (±23.35)</td>
</tr>
<tr>
<td>Theory of mind condition</td>
<td>88.49 (±17.03)</td>
</tr>
<tr>
<td>Character control condition</td>
<td>94.29 (±16.51)</td>
</tr>
<tr>
<td>Object control condition</td>
<td>66.66 (±18.86)</td>
</tr>
<tr>
<td>False beliefs (total theory of mind score)</td>
<td>73.33 (±21.06)</td>
</tr>
<tr>
<td>First-order theory of mind condition</td>
<td>58.69 (±19.73)</td>
</tr>
<tr>
<td>Second-order theory of mind condition</td>
<td>96.44 (±8.31)</td>
</tr>
<tr>
<td>Affective theory of mind</td>
<td></td>
</tr>
<tr>
<td>Face/eyes test</td>
<td></td>
</tr>
<tr>
<td>Basic emotions</td>
<td>55.33 (±14.07)</td>
</tr>
<tr>
<td>Complex emotions</td>
<td>44.15 (±18.24)</td>
</tr>
<tr>
<td>Composite theory of mind**</td>
<td></td>
</tr>
<tr>
<td>Tom’s taste</td>
<td></td>
</tr>
<tr>
<td>Experimental condition</td>
<td>63.64 (±13.81)</td>
</tr>
<tr>
<td>Control-like condition</td>
<td>65 (±14.49)</td>
</tr>
<tr>
<td><strong>Subjective assessment</strong></td>
<td></td>
</tr>
<tr>
<td>Theory of mind scale (total score)*</td>
<td>39.70 (±10.59)</td>
</tr>
<tr>
<td>Cognitive theory of mind subscale</td>
<td>38.43 (±18.89)</td>
</tr>
<tr>
<td>Affective theory of mind subscale</td>
<td>46.39 (±12.26)</td>
</tr>
</tbody>
</table>

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*Analyses were conducted on 14 patients with semantic dementia.
**Analyses were conducted on 10 patients with semantic dementia.
*Analyses were conducted on 12 patients with semantic dementia.

Otherwise, analyses were conducted on 15 patients with semantic dementia. Significant comparisons after false discovery rate corrections are in bold. **ns** = not significant; **ToM** = theory of mind.
Results

Objective theory of mind assessment

Attribution of intention task

Intergroup comparisons
In the experimental theory of mind condition, Mann–Whitney comparisons revealed a significant effect of group ($U = 92, z = 3.63, P < 0.001$), indicating that the group with semantic dementia performed worse than controls. However, patients with semantic dementia did not significantly differ from the healthy controls on the two control conditions.

Intragroup comparisons
In the patient group, Wilcoxon pairwise comparisons revealed a significant difference between the theory of mind and both control conditions: performances in the control conditions with characters/objects were better than performances in the theory of mind condition ($z = 2.86/3.06, P < 0.005$ for both). No difference was found between the two control conditions. In the control group, analyses revealed a significant difference between the theory of mind condition and the control condition with objects, with a better performance in the control condition ($z = 2.02, P < 0.05$).

False-belief task

Intergroup comparisons
In the experimental theory of mind condition, Mann–Whitney comparisons revealed a significant effect of group in the first-order condition ($U = 124, z = 3.16, P < 0.005$) as well as in the second-order one ($U = 120.5, z = 3.16, P < 0.005$), with patients with semantic dementia performing worse than controls. No significant intergroup difference was found in the control condition.

Intragroup comparisons
Analyses showed a significant effect of the theory of mind condition in both the semantic dementia ($z = 3.30, P = 0.001$) and healthy control ($z = 3.75, P < 0.001$) groups: performances in the total (first- and second-order) theory of mind condition were poorer than in the control one (Table 3). Moreover, a significant difference was found according to the level of representations, with poorer performances on second-order false beliefs than on first-order ones for both patients with semantic dementia ($z = 2.67, P = 0.01$) and healthy controls ($z = 2.91, P < 0.005$).

The Eyes test

Intergroup comparisons
A significant effect of group was found in both the basic emotions condition ($U = 103.5, z = 3.52, P < 0.001$) and the complex emotions conditions ($U = 175, z = 1.99, P = 0.05$), in that patients with semantic dementia performed worse than healthy controls.

Intragroup comparisons
Analyses showed a significant effect of condition in both the semantic dementia ($z = 2.17, P = 0.05$) and healthy control ($z = 3.65, P < 0.001$) groups, in that they performed better in the basic emotions condition than in the complex emotions condition.

Tom’s taste

Intergroup comparisons
An effect of group was found in both the theory of mind ($U = 39, z = 3.81, P < 0.001$) and the control-like ($U = 54.5, z = 4.26, P < 0.001$) conditions, in that patients with semantic dementia performed worse than healthy controls (Table 3).

Intragroup comparisons
Analyses showed a significant effect of condition for both the healthy controls ($T = 17, z = 3.42, P < 0.001$) and patients with semantic dementia ($T = 1.5, z = 2.65, P < 0.01$), in that they performed better in the control condition than in the theory of mind condition.

Analysis of choices of responses
In order to understand the patients’ deficit in this complex theory of mind task, Mann–Whitney comparisons were conducted for each category of responses. Results (Fig. 3A) showed that patients with semantic dementia gave more context-related responses (i.e. taking the context but not Tom’s preference into account; $U = 49, z = -3.62, P < 0.001$) and unsuitable responses ($U = 105, z = -2.53, P < 0.05$) than the controls when they provided incorrect responses.

Analysis of types of justifications
Mann–Whitney comparisons were conducted on each type of justification. Results (Fig. 3B) indicated that patients with semantic dementia justified their responses significantly less on the basis of Tom’s preference ($U = 46.5, z = 3.64, P < 0.001$) and more on their self-views ($U = 119, z = -2.19, P = 0.05$) than the control group.

Subjective theory of mind assessment

Intergroup comparisons
Mann–Whitney comparisons revealed an effect of group on the affective theory of mind subscale ($U = 72.5, z = 3.45, P < 0.001$); patients with semantic dementia estimated their affective theory of mind abilities more negatively than the healthy controls. No difference was found in the cognitive theory of mind subscale ($U = 147, z = 1.65, not significant$).

Intragroup comparisons
Analyses showed a significant difference between the two subscales for the healthy control group ($T = 122, z = 2.47, P = 0.01$), in that they judged their affective theory of mind abilities more favourably than their cognitive ones. Even though patients with semantic dementia scored less well on the cognitive theory of mind subscale, the difference was not significant.

To go one step further, we conducted a supplementary analysis by computing two new scores illustrating theory of mind insight in patients with semantic dementia. First, we calculated two objective theory of mind $z$-scores: (i) a cognitive theory of mind $z$-score combining performances on the attribution of intention (theory of mind condition) and false-belief tasks (total score in the theory of mind condition); and (ii) an affective theory of mind...
z-score for the complex emotions condition of the Eyes test. Second, we calculated subjective cognitive and affective theory of mind z-scores for the cognitive and affective theory of mind subscales, respectively. Finally, we calculated the difference between the objective and subjective scores using the following formula: (i) objective cognitive z-score minus subjective cognitive z-score for the cognitive theory of mind insight measure; (ii) objective affective z-score minus subjective affective z-score for the affective theory of mind insight measure. Each score was then compared with the normal standard (i.e. zero) (Table 4). The closer to zero the score was, the greater the cognitive (or affective) theory of mind insight. Results showed that patients with semantic dementia significantly differed from the reference value only for cognitive theory of mind insight, indicating that they were unaware of their cognitive theory of mind disabilities, but not their affective ones. Thus, this analysis confirmed the dissociation observed in the theory of mind scale.

Overall, patients with semantic dementia performed poorly on several objective tasks probing cognitive and affective theory of mind. They also gave lower ratings than the healthy controls on the sole subjective affective theory of mind scale.

In order to obtain more stringent results, we used the Benjamini–Hochberg (1995) procedure for controlling the false discovery rate. Results were similar, except for the complex emotions condition of the Eyes test and the unsuitable responses and the ‘Self’ justification condition of Tom’s taste, which became non-significant (Table 3).

### Table 4 Comparison between patients with semantic dementia theory of mind insight and normal standard

<table>
<thead>
<tr>
<th></th>
<th>Z-score mean</th>
<th>Reference value</th>
<th>t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive theory of mind insight measure</td>
<td>-0.96</td>
<td>0.00</td>
<td>-2.28</td>
<td>0.04</td>
</tr>
<tr>
<td>Affective theory of mind insight measure</td>
<td>0.77</td>
<td>0.00</td>
<td>1.76</td>
<td>ns</td>
</tr>
</tbody>
</table>

ns = not significant.
mind tasks, and a loss of insight of their cognitive theory of mind impairment.

As regards cognitive theory of mind, patients with semantic dementia failed to infer either the intentions or the false beliefs of a character involved in a social scenario. This deficit could not be explained by a visual semantic disorder or a comprehension deficit, as they achieved normal scores in the two control conditions. In the test of attribution of intention, for instance, patients with semantic dementia were particularly poor at predicting a character's action, though not the future of characters without intention or of physical objects. This result could be explained by the major temporal lobe abnormalities that characterize these patients, especially in the left temporal pole. Using a similar theory of mind task in a functional MRI study with healthy participants, Völlm et al. (2006) found that the temporal poles, with a left-sided preponderance, were activated in the theory of mind condition but not in the two control conditions (i.e. physical causality relative to a character without intention or a simple object). Likewise, Walter et al. (2004) reported similar results with an equivalent task of deducing other people’s intentions.

We also showed a link between visual episodic memory and the theory of mind condition of this task. The relationship between episodic memory and mentalizing has already been flagged up in developmental studies (Perner, 2000), and neuroimaging studies have shown that the two processes are mediated by similar brain networks, including the hippocampus (Rabin et al., 2010; Spreng and Grady, 2010; Perry et al., 2011). According to Perry and colleagues (2011), mentalizing may be based on self-projection, where the individual recalls experiencing a similar event. Thus, patients with semantic dementia may have attempted to rely on their memories of social experiences in order to comprehend the protagonists' intentions. While not compensating for their theory of mind deficit, episodic memory abilities did account for a proportion of the variability in their theory of mind performances in the attribution of intention test.

As far as the false-belief task is concerned, we showed that patients with semantic dementia had difficulties inferring the characters’ beliefs, especially when they had to take two perspectives simultaneously into account. According to Samson et al. (2005), two components of theory of mind are typically involved in classic false-belief tasks: inhibition of one’s own perspective and inference of another person’s mental state. In our task, participants could only choose between two responses: one referring to the character’s mental state, the other to the reality of the scenario. It is, therefore, entirely possible that the patients’ erroneous responses reflected a deficit in the inhibition of their own perspective, given that they obviously understood the scenario properly. However, it is more likely that patients with semantic dementia presented a specific disturbance in the inference of mental states. First, their performance declined according to the degree of inference, such that second-order theory of mind was more impaired than first-order one. Secondly, no relationship was found between the false-belief task and the inhibition performance of patients with semantic dementia. The significant correlation between the Concept subscale of the Mattis scale and second-order false-belief theory of mind suggests that the patients’ semantic impairment may have interfered with and/or impoverished their complex reasoning.

Most studies using false-belief tasks in healthy adults have underlined the involvement of the temporal regions, as well as the median prefrontal cortex and more especially, the anterior cingulate cortex (Gallagher et al., 2000; Vogeley et al., 2001; Frésl and Von Cramon, 2002). Moreover, patients with the behavioural variant of FTD with bilateral atrophy in the orbitomedial region and anterior temporal lobe have been shown to perform poorly on first- and second-order tests (Lough et al., 2001; Adenzato et al., 2010). The patients with semantic dementia in the current study presented broad left-sided temporal atrophy, together with hypometabolism in similar areas, but also in the median orbitofrontal and anterior cingulate regions, which may explain their cognitive theory of mind decline.

Overall, performances were better in the control condition than in the theory of mind condition for both groups, raising the question of differences in task difficulty. To address this issue, two points need to be considered. First, ageing is known to affect theory of mind, such that healthy older people perform worse than younger people on both attribution of intention and false-belief tests (Duval et al., 2011). This normal ageing effect on theory of mind abilities may therefore explain why the control group performed better in the control condition than in the theory of mind condition. Secondly, in the attribution of intention test, we used exactly the same format of stories and subsequent questions in all three conditions. Thus, the differences between them must have stemmed from the nature of the representations being manipulated. Consequently, task difficulty would seem to be an inadequate explanation for the impairment of cognitive theory of mind observed in patients with semantic dementia. Dysfunction of theory of mind processes (inference and manipulation of intention and epistemic representations) is more likely to account for their impaired performances.

In the affective theory of mind test, we found that patients with semantic dementia performed significantly worse than healthy controls on both basic and complex emotions recognition. Regarding the basic emotion condition, our results are consistent with numerous previous studies showing an emotional recognition processing disorder in semantic dementia via facial expression tests (Rosen et al., 2002, 2004; Calabria et al., 2009). Moreover, authors have found that negative emotion recognition is particularly badly affected. Our results may have been influenced by an emotional valence bias, since only 30% of items illustrated positive emotions (e.g. happiness, surprise), compared with 70%, negative ones (e.g. sadness, fear, anger). Post hoc analyses revealed significant differences in the recognition of basic emotions according to valence in both groups (data not shown): in the patients with semantic dementia, positive and negative emotions were recognized in 80% and 45.90% of cases, respectively, whereas these figures were 81.33% and 66.86% for the healthy controls. Consistent with the literature (Rosen et al., 2002, 2004), the only significant intergroup difference concerned negative emotions. This deficit of patients with semantic dementia could be explained by brain abnormalities other than their anterior temporal defects. Numerous studies in healthy and neurological populations have pointed to the crucial involvement of the amygdala, insula,
fusiform gyrus or superior temporal gyrus in the recognition of emotion, including negative emotion (Anderson et al., 2000; Adolphs, 2002; Rosen et al., 2002; Omar et al., 2010). The considerable atrophy and hypometabolism of these brain regions in our patients with semantic dementia may thus have impaired their basic negative emotion processing.

Concerning complex emotions, we also found significant differences between our patients with semantic dementia and controls, and these differences might have been even greater given the floor-level scores obtained by the control group for several emotions (data not shown). This result is not surprising, given that previous studies have reported the involvement of the temporal poles in complex emotion processing in the healthy population (Burnett and Blackmore, 2009). Although numerous studies support the notion that complex (or social) emotion processing is sustained by a more extensive brain network than basic emotions, temporal regions represent key processing sites (Britton et al., 2006; Takahasi et al., 2008; Castelli et al., 2010). Researchers have also demonstrated that complex emotions are processed in the amygdala (Adolphs et al., 2002). In the latter study, authors found that patients with unilateral or bilateral amygdala damage failed to recognize social emotions in the Eyes test. Hence, the atrophy and hypometabolism in the temporal pole and amygdala in our semantic dementia patient group may explain their failure to infer complex emotions.

Likewise, in the composite theory of mind task, the semantic dementia patient group performed poorly in both the experimental and control conditions. Given that the control condition checked the inferences they made from the characters' pictures alone (i.e. without any context or response pictures), their failure in the experimental condition must therefore have been related to their inability to deduce the character's preference. The detailed analyses of responses in the theory of mind condition confirmed their tendency to choose more context-related responses (i.e. without taking the character's preference into account) than the controls did. Interestingly, the patients with semantic dementia were more likely than the controls to justify their choices on the basis of their own preferences or other unexpected criteria. This fits in with previous behavioural studies in patients with semantic dementia reporting their self-centredness and egocentric world view (Snowden et al., 2001). Patients with semantic dementia often present abnormal egocentric behaviour, referred to as ‘behavioural egocentrism’ by Belliard et al. (2007). While its origin is still unknown, this disorder seems to be specific to semantic dementia (compared with the behavioural variant of FTD) and could be partially related to theory of mind impairment (Bon et al., 2009). A future study could be conducted to understand this pattern of results by exploring relations between theory of mind scores and behavioural egocentrism measures. In any event, our participants’ performance on the composite theory of mind task clearly indicates that patients with semantic dementia have difficulty understanding other people's cognitive and affective mental states when these are embedded. Considering the contextual responses and personal justifications made by patients with semantic dementia in the test, we suggest that they mainly rely on contextual knowledge and their own personal interests when dealing with social interactions. Since our test was designed to explore theory of mind under conditions that corresponded to the daily social context, it inherently encompassed both affective and cognitive theory of mind, thus preventing us from distinguishing between the two. We therefore cannot conclude whether the deficit we observed resulted from a cognitive impairment (inferring thought), affective impairment (inferring preference) or both. Future research is needed to unravel this issue.

Finally, our subjective cognitive and affective theory of mind subscale findings suggest that the patients with semantic dementia were aware of their affective theory of mind disturbance but not of their difficulty in inferring and understanding the intentions and beliefs of others. In addition, despite massive semantic memory disturbance and episodic memory failures, patients with semantic dementia did not complain more than controls about their daily memory functioning, as attested by their responses to the Cognitive Difficulties Scale. Taken together, these results suggest an impairment of cognitive functioning awareness in our patients with semantic dementia. Anosognosia has been widely reported in frontotemporal lobar degeneration (Eslinger et al., 2005; O’Keeffe et al., 2007): patients tend to underestimate the extent of their cognitive and behavioural changes, even if metacognition deficits are more severe in the behavioural variant of FTD than in semantic dementia and affect a broader range of cognitive domains (Eslinger et al., 2005; Zamboni et al., 2010). Anosognosia for behavioural disability has been associated with right temporal atrophy in patients with FTD or corticobasal syndrome (Zamboni et al., 2010) and with left temporal pole hypometabolism in patients with the behavioural variant of FTD (Ruby et al., 2007). The atrophy and hypometabolism of these structures in our own patients with semantic dementia may have contributed to their lack of awareness of cognitive theory of mind deficits. We observed a significant correlation between the cognitive theory of mind subscale and literal fluency performance in the patients with semantic dementia. Because the literal fluency task involved strategic processes, it is tempting to conclude that this result reflects the involvement of executive functions in making such self-assessments. However, in semantic dementia, literal fluency performance is determined mainly by semantic memory capacity and left temporal cortex metabolism (Lainsley et al., 2009). Accordingly, fluency performances can be regarded as an index of disease severity in this pathology and we can assume that patients become increasingly unaware of their cognitive theory of mind difficulties as the disease progresses.

The awareness of their affective theory of mind disturbance in patients with semantic dementia is more surprising. In a previous study, Eslinger et al. (2005) found that patients with semantic dementia overstated their empathy ability. These discrepant results may stem from the way in which metacognition was assessed; while Eslinger and colleagues (2005) compared reports of patients and their relatives, we compared the subjective assessments of patients with those of the healthy controls. Thus, our study revealed a dichotomy between cognitive and affective theory of mind insight in patients with semantic dementia. Given the impact of theory of mind deficits, especially affective theory of mind deficits, on family and social interactions, the patients' relatives may well have attempted to force the patients
to consider their affective difficulties, thus facilitating their aware-
ness. Other studies need to be conducted in order to understand
this pattern of results more fully.

Overall, this study provides evidence of an objective impact of
semantic dementia on cognitive and affective theory of mind.
While the patients’ semantic impairment may have contributed
to their poor theory of mind performances, it is unlikely to pro-
vide the full explanation. The patients in our study were still in
the mild stage of the disease and we used procedures designed to
minimize the confounding effect of the patients’ semantic impair-
ment on their theory of mind performance. It is interesting to note
that the correlation analysis between the semantic memory
scores and the theory of mind performances revealed only one
significant correlation (between the Concept subscale of the
Mattis scale and the second-order condition of the false-belief
task). The patients inference ability was impaired for intentions,
beliefs and affective states. The cognitive theory of mind deficits in
patients with semantic dementia would appear to be associated
with the cerebral atrophy in the left temporal lobe and hypome-
tabolism in the temporal lobes and medial frontal cortex.
Impairment of the affective theory of mind would seem to be
the result of abnormalities in the temporal regions and amygdala.
Finally, the subjective assessment of theory of mind suggests a
dichotomy between cognitive and affective aspects with anosog-
nosia only for cognitive theory of mind disabilities in the early to
moderate stages of the disease. Hence, patients with semantic
dementia differ from patients with the behavioural variant of
FTD, who present deficits on all objective theory of mind tasks
(Gregory et al., 2002) and severe anosognosia. Patients with
semantic dementia were shown here to display deficits in inter-
subjectivity due to a cognitive and affective theory of mind impair-
ment. We therefore suggest that it is this difficulty in attributing
mental states to others that leads patients with semantic dementia
to become focused on themselves, which would explain their
self-centred responses to the composite theory of mind task
and/or their general behavioural egocentrism described in
literature. In turn, behavioural egocentrism may also influence
theory of mind abilities and interpersonal relationships. However,
our results must be viewed with caution, given the heterogeneous
patterns of theory of mind deficits displayed by the patients,
as well as the use of a unique task of affective theory of mind.
They now need to be confirmed and reinforced in further experi-
ments exploring the link with their behavioural egocentrism in
greater detail.

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