CHAPTER 31

Real-world Consequences of Social Deficits: Executive Functions, Social Competences, and Theory of Mind in Patients with Ventral Frontal Damage and Traumatic Brain Injury

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Abstract

A variety of brain disorders may give rise to social deficits. Social neuroscience is in a position to help such patients by providing objective methods of defining and measuring social competencies. Such measurements can provide researchers with a more detailed picture of the components of social competencies, assist clinicians in making appropriate treatment recommendations, and provide a foundation for further research into rehabilitation programs tailored to remediating specific and well-defined social difficulties. This chapter reviews existing tools for measuring social competencies, and examines the relationships between these tools and measures of executive functions. In doing so, it discusses the need for more precise use of the terms "executive functions" and "theory of mind."

Keywords: traumatic brain injury, frontal lobes, ventral frontal cortex, orbitofrontal cortex, theory of mind, social competence, social skills, executive functioning, executive function, neuropsychological assessment

Introduction

A variety of brain disorders may give rise to social deficits. Social neuroscience is in a position to help such patients by providing objective methods of defining and measuring social competencies. Such measurements can provide researchers with a more detailed picture of the components of social competencies, assist clinicians in making appropriate treatment recommendations, and provide a foundation for further research into rehabilitation programs tailored to remediating specific and well-defined social difficulties. In this chapter, we review existing tools for measuring social competencies, and examine the relationships between these tools and measures of executive functions. In doing so, we discuss the need for more precise use of the terms "executive functions" and "theory of mind." Because neither refers to a unitary underlying function, we encourage researchers to link the use of these terms to specific tests or sub-processes, to avoid conflation of separable processes. We review several measures of social competence, focusing on tests of the ability to infer others' internal, mental states. The chapter focuses on how these measures have been used with patients who have nonpenetrating traumatic brain injuries (TBI) and/or damage to the ventral frontal cortex, because they are the largest group of patients with acquired brain damage who present with social deficits (Langlois, Rutland-Brown, & Wald, 2006). We find that only Sarcasm/Irony Detection tasks, the Recognition of Faux Pas Task, and The Awareness of Social Inference Test (TASIT) reliably differentiate these patients from healthy matched controls, and correlate with patients' real-world outcomes. Current clinical practice assesses patients with ventral frontal damage and TBI with objective, performance-based measures of *cognitive* abilities, whereas *social* competencies are often assessed with questionnaires or qualitative observations. We encourage social neuroscientists to work with neuropsychologists and neurologists to bring objective assessments of a wide range of social competencies into the clinic, where they can guide rehabilitation, and improve patients' and their loved ones' lives.

Background

As a society, we recognize that someone with a stroke affecting her motor cortex cannot help the fact that she cannot move one side of her body. We recognize that someone with Alzheimer's disease cannot help the fact that he cannot remember who came to visit this morning. With social deficits, however, our society tends not to recognize that some people with neurological damage might have difficulty reading social cues, inhibiting impulses, or being aware of how their social behavior is inappropriate. The general attitude still seems to be that someone who is socially inappropriate has a personal or moral failing.

There is little public education to broadcast a central insight of social neuroscience: Deficits in social behavior can have a neurological origin because parts of the brain are specialized for processing social and emotional information. Those parts of the brain have been called "the social brain" by social neuroscientists, and include frontal and temporal areas (Brothers, 1990). The lay public does not necessarily know about the existence of specialized systems in the brain for social information-processing. When brain injury is called "a hidden disability" (e.g., Abouhamad, 1999)), one meaning of that phrase is that people cannot see the source of someone's inappropriate behavior, that they cannot see that the person now has tremendous difficulty controlling impulses, and accurately perceiving social cues. People, even family members and friends, get angry, offended, and may reject the person with a brain injury because they misunderstand the behavior's source. Such social consequences have profound and potentially long-term effects on patients' quality of life (Langlois et al., 2006; McDonald, Flanagan, Rollins, & Kinch, 2003; Ownsworth & Fleming, 2005; Ponsford, Draper, & Schonberger, 2008). Given that some neurological patients have significant deficits in social judgment and in producing appropriate social behavior, it is imperative that social neuroscientists discuss and measure the real-world consequences of damage to the social brain, and devise and publicize new tools for asssessing problems with social competencies objectively. Social neuroscience must be science in the public interest.

What is Needed to Assess Patients with Social Deficits?

A variety of brain disorders may give rise to social deficits: traumatic brain injury (e.g., Langlois et al., 2006), damage to the amygdala (e.g., Brothers, Ring, & Kling, 1990; Broks et al., 1998; Adolphs, Tranel, & Damasio, 1998; Stone, Baron-Cohen, Calder, Keane, & Young, 2003), damage to the frontal cortex from trauma, surgery, stroke, or frontotemporal dementia (e.g., Stone, 2000; Neary, 1999; Tekin & Cummings, 2002), damage to the cerebellum (e.g., Shevell & Majnemer, 1996; Ozonoff, Williams, Gale, & Miller, 1999), or damage to the temporal lobes (Brothers, 1990; Rosen et al., 2002; Park et al., 2003). The largest group of people who are at risk for social and emotional problems is the group suffering nonpenetrating traumatic brain injuries (TBI; Langlois et al., 2006), causing damage predominantly in the ventral frontal and anterior temporal regions (e.g., Devinsky & D'Esposito, 2004; Levine et al., 2008). Accordingly, here we focus specifically on people with damage to the ventral frontal cortex, also called the orbitofrontal cortex, and people with TBI, including those with focal damage to the ventral frontal cortex. (See Figure 31.1 for diagram of frontal cortex.) The two groups of patients overlap, but are not exactly the same. In many research studies of patients with ventral frontal damage, the most common cause of damage is traumatic brain injury, though some patients may have damage from surgery for tumors, or other sources. (The term "ventromedial frontal damage" means lesions that affect *both* the ventral frontal cortex and medial frontal cortex, —often caused by removal of a tumor. See Figure 31.1.) As noted above, particularly in moderate to severe TBI, damage to the ventral frontal cortex is one of the most common lesion locations. Studies examining the physics of TBI have shown

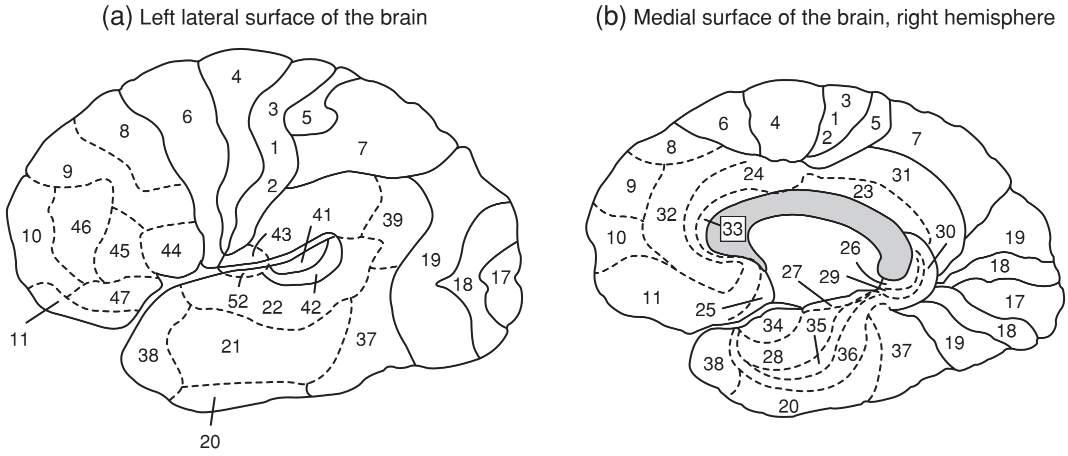

Fig. 31.1 The brain, with Brodmann areas marked (anatomical regions determined by differences in cell structure). (a) View of the left hemisphere from the outside (lateral view). Ventral frontal cortex in this view would include primarily Brodmann area 11, but also area 47 and ventral parts of area 10. Dorsolateral prefrontal cortex would include areas 6, 8, 9, and dorsal parts of 10 & 46. (b) View of the right hemisphere from the center of the brain (medial view). Ventral frontal cortex would include Brodmann areas 11, 25 and possibly ventral parts of area 32. Medial frontal cortex would include areas 24, 32, and area 33 (anterior cingulate cortex). Dorsolateral prefrontal cortex would include areas 6, 8, 9 on this medial view.

that the frontal lobes exhibit the most deformation by being compressed forward against the skull, whereas more posterior regions exhibit stretching, which shears fiber pathways (Bayly et al., 2005). Furthermore, as the brain bounces around inside the skull following a severe blow, the bony protrusions in the skull above the eyes, directly below the ventral frontal cortex, can bruise and tear neural tissue, causing focal lesions.

Patients with TBI also have diffuse axonal injury because of stretching and shearing of axons and toxic chemical events started by the trauma that unfold for hours or days after the injury (e.g., Kraus et al., 2007; McCrea, 2007; Kumar et al., 2009). Thus, while people with TBI are at high risk for ventral frontal dysfunction, they are also likely to have difficulties from multiple diffuse injuries affecting various brain regions, potentially leading to several sources of deficits in social competencies and cognition. Therefore, when we say, below, "patients with ventral frontal cortex damage and/or TBI," these two groups should be understood as overlapping but not identical.

Social deficits may result from impairments in multiple cognitive and affective systems, and as yet, we do not have a precise model of all of the systems underlying social behavior. Social neuroscience is a new and burgeoning field for this precise reason: there is much to discover about how the social brain works. Defining social information-processing rigorously is a difficult problem, because so many processes are involved. For example, patients with ventral frontal damage may suffer from both a difficulty reading other people's emotional expressions (Hornak, et al., 2003; Hornak, Rolls, & Wade, 1996) and a difficulty inhibiting inappropriate remarks in a particular social context (Berlin, Rolls, & Kischka, 2004; Cummings, 1993; Kim, 2002). Although both of these difficulties can be categorized as deficits in the *social* realm, they may result from impairments in different underlying systems, and would entail different types of treatment. In order to get a full picture of the many factors that may influence inappropriate social behavior, clinicians need to assess cognitive *and* social functions.

Psychological assessments can use any of four methods to evaluate a patient's competence in a particular domain. First, performance measures are objective tests requiring patients to demonstrate competence by solving a problem in that domain. Second, informant reports are questionnaires given to caregivers to report on patients' competence. Third, self-reports are questionnaires given to patients to report on their own competence, or are patients' own unstructured, qualitative reports of their experiences. Fourth, clinicians use their own qualitative judgments, or those produced by family and friends to assess certain behaviors.

All four of these methods have value. Some phenomena, such as emotional distress, are inherently subjective, internal experiences, making a self-report necessary to gather this information. Other behaviors, such as easily losing one's temper, may not occur in the presence of strangers or in formal settings, making the behaviors difficult to observe in the clinic or laboratory. Reports about patients' behaviors in multiple settings are a rich source of information, and should continue to be part of assessments of social and emotional problems. Nevertheless, objective, performance-based measures can more precisely describe particular abilities: for instance, does socially inappropriate behavior result from a problem with eye contact, interpreting facial expressions, or making inferences about others' intentions? A clinician's qualitative report about a patient's cognitive abilities such as "the patient seemed bright and solved everyday problems without too much effort" is not taken seriously *by itself* as an assessment of cognition; however, a qualitative report such as "the client was often socially inappropriate and made offensive remarks" is often taken more seriously. We would like to see an increase in the use of performance measures to assess social and emotional abilities, in order to increase the objectivity and utility of these assessments.

Social neuroscience has advanced enough in the last decade to be able to provide clinicians with performance measures of several social and emotional competencies: facial expression recognition, empathy, theory of mind, eye-gaze tracking, emotion regulation, understanding and using language pragmatics. Many of these measures have been used in the experimental literature more than in the clinical literature, and therefore not all measures have population norms gathered in large samples, but there are enough useful social competence tasks for researchers to begin collecting norms. We will review some of these new tasks in this chapter, and recommend some directions for research.

The Interaction of Executive Functions and Social Competencies

Social interaction is cognitively complex and requires multitasking, applying memories to a changing stream of behavior, tracking changes in social context and rewards, selecting behaviors from a range of options, and rapidly changing the focus of attention. Such situations make high demands on executive functions, a group of cognitive abilities including working memory, distraction-suppression, planning, problem-solving and the organization of behavioral output. Functional neuroimaging has revealed that tests of executive functions are associated primarily with activation in dorsolateral frontal regions (e.g., Derrfuss, 2005), rather than ventral frontal regions. (See Figure 31.1 for a diagram of ventral frontal and dorsolateral frontal regions.)

Deficits in executive abilities can cause problems in social interaction, just as they do in other complex tasks. Imagine a common social situation: a group of people are standing together at a party, talking. One man tells a political joke, and while some people in the group laugh, a couple of people frown in disapproval, and an awkward moment ensues. A socially skilled person in the group then changes the topic to something politically neutral. Suppose one woman in the group has a deficit in executive functioning, specifically, a deficit in the ability to shift her attention flexibly. She might continue to focus on the man who told the joke, without shifting her attention to the reactions of the others in the group. She might be puzzled by the change in conversational topic, or might tell another political joke, having missed important social information by not attending to it. An attentional deficit is not specifically social, but, as seen in this example, it can cause social problems. To predict social outcomes for neurological patients with social behavior difficulties, therefore, a clinician will need to assess executive functions thoroughly.

Although it is *necessary* to assess executive functions in people with social deficits caused by neurological damage, it is not *sufficient*. Clinicians must also assess social competencies per se to provide the best information to patients and their families about the difficulties they are likely to encounter, and to provide detailed recommendations for rehabilitation. Certain social competencies might be completely independent of certain executive abilities. Impaired recognition of emotion from facial expressions or voice, or the ability to tell if someone might be cheating in a deal can cause social difficulties even if some executive functions are intact (Stone et al., 2002; Hornak et al., 1996). Researchers have described patients with focal lesions to ventral frontal regions resulting in social dysfunction, but who have some spared executive abilities (e.g., Eslinger & Damasio, 1985; Dimitrov, Phipps, Zahn, & Grafman, 1999; Stone et al., 2002). (The assessments of executive functions in these patients were not exhaustive, and thus some executive deficits may have been missed.) Social and executive skills have also been dissociated in patients with the frontal variant of fronto-temporal dementia, a progressive disease first causing atrophy in the ventral frontal cortex. Such patients present with personality changes and social and emotional disruptions, but generally normal performance on some commonly used tests of executive functions (Gregory, 1999; Lough, Gregory, & Hodges, 2001). Finally, performance on some executive tests does not predict social performance in people with TBI (Milders, Fuchs, & Crawford, 2003). Thus, there is mounting evidence that social and executive functioning are at least partly independent of one another.

The Nature of Executive Functions and the Most Effective Measures

Part of the confusion about executive functions outlined here comes from a tendency in many neuropsychological studies to assess what they call "executive function" (singular), referring to the "function" as if it were the same ability tapped by different tests (e.g., Bach, Happé, Fleminger, & Powell, 2000; Lough et al., 2001; McPherson, Fairbanks, Tiken, Cummings, & Back-Madruga, 2002; Weyandt, 2005). However, the many different tasks used to assess executive functions do not all necessarily intercorrelate and do not all measure the same thing. Thus, "executive function" (singular) is a problematic term because it does not refer to a unitary ability, but rather to a *set* of cognitive abilities. The term was originally introduced to refer to the "central executive," the controller of the short-term memory system, which allocates attentional resources, and off-loads some processing demands to its "slave systems," the articulatory loop and the visuospatial sketch pad (Baddeley, 1981). Since then, "executive functions" has come to mean a collection of cognitive abilities, usually including working memory, sequencing, planning, set-shifting, cognitive flexibility, flexible control of attention, task-switching, establishing a hierarchy of goals, inhibition of competing action programs or cognitive processes, response inhibition and selection, and the application of strategic behavior. Tests of these various abilities are by no means interchangeable.

No one truly claims that there is a unitary "executive function"; it is rather that the term has come to be used as if there were. In fact, factor analyses do not show a unitary factor structure for different tests of executive functions (Pennington, 1997, Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000; Busch, McBride, Curtiss, & Vanderploeg, 2005). Furthermore, because the results of any given factor analysis of executive functions depend on which particular cognitive tests are included in the analysis, there can be no definitive factor analysis of executive functions. Also, the way that factors from the analyses are named may vary from one research group to another. Nevertheless, there is some overlap in the factors discovered for executive functions. Pennington (1997) analyzed executive functions in a group of typically developing children and children with developmental disorders, and found three factors that were consistent across both groups: 1) working memory, 2) flexibility/set-shifting, and 3) motor inhibition. Researchers using somewhat different tests report a slightly different three-factor solution: 1) information updating and monitoring, 2) set shifting, and 3) inhibition (Miyake et al., 2000). In a large sample of patients with TBI, Busch and colleagues (2005) also found three factors: 1) cognitive control, particularly of material in working memory; 2) higher-order executive functions including both self-generative behavior and cognitive flexibility/set shifting; and 3) error control failures, especially of inhibition of errors. There are clear similarities in the contents of the three sets of three-factor accounts of executive functions. Others, however, have suggested a five-factor structure for executive functions, including 1) inhibition (the ability to suppress a prepotent response); 2) planning (goal-directed planning and execution of behavior, which includes insight); 3) memory organization (temporal sequencing of memory); and 4) positive and 5) negative personality changes that co-occur with the cognitive syndrome (Burgess, et al., 1998). Still others have argued that executive functions can be reduced to working memory, and that compromised working memory affects all executive functions (Braver, Cohen, & Barch, 2002; Miller, 2007).

Some of the same researchers who have investigated the factor structure of executive functions have argued that the original theoretical formulation of executive functions is no longer clinically useful, and that a new set of tests ought to be developed that are focused on functional evaluations and ecological validity (Burgess et al., 2006). We agree, and encourage, at the very least, the use of the plural w"executive functions," to denote the multiplicity of cognitive processes that the concept comprises. We would also like to suggest that authors always describe the specific task or function that is implicated in the assessment of executive functions, to add clarity to both research and clinical interpretations. Rather than saying, for example, "executive function was correlated with patients' behavioral problems," a more specific statement such as "perseverative errors on the Wisconsin Card Sorting Test were correlated with patients' scores on the

Neuropsychiatric Index" would be both more accurate and more useful, and would reduce some of the conceptual confusion in the executive functioning literature. Finally, because of the plurality of cognitive abilities summed up by the term "executive functions," clinicians should use multiple tests to assess these multiple abilities (Gioia & Isquith, 2004).

Assessments of Executive Functions in Patients with Ventral Frontal Damage and TBI

Common Tests

Commonly used tests of executive functions include the Trail Making Test, Parts A & B, a test of sequencing and working memory (e.g., Reitan, 1958); verbal fluency tests, such as F-A-S or semantic fluency (e.g., Benton & Hamsher, 1989); nonverbal design fluency tests (e.g., the Design Fluency subtest of the Delis-Kaplan Executive Function System (D-KEFS)); the Stroop color-word interference test, a test of cognitive inhibition (e.g., Stroop, 1935); cognitive estimates tasks, measuring ability to estimate without strong external cues (e.g., Shallice & Evans, 1978); the Wisconsin Card Sorting Test (WCST) or the California Card Sorting Test, measuring several abilities, including set-shifting (e.g., Berg, 1948; Milner, 1964; Delis, Kaplan, & Kramer, 2001); the Tower of London (e.g., Culbertson & Zillmer, 2001) and the Tower of Hanoi (e.g., Samet & Marshall-Mies, 1987), measuring sequencing and planning, Go/No-go tasks, measuring inhibition (e.g., Robertson, Manly, Andrade, Baddeley, & Yiend, 1997); and the Hayling Sentence Completion Test, measuring inhibition (Burgess & Shallice, 1997). There are also batteries, such as the Delis-Kaplan Executive Function Battery (D-KEFS; Delis et al., 2001), which contain a number of these tasks as subtests. Among these performance-based measures of frontal lobe functions, each task has different strengths and weaknesses (see Table 31.1).

Available norms on tests

Appropriate normative data that are stratified by age and education are available for Trail Making (Strauss et al., 2006), Verbal Fluency (Strauss, Sherman, & Spreen, 2006), and Card Sorting tests (Heaton, Chelune, Talley, Kay, & Curtiss, 1993; Delis et al., 2001). Norms stratified by age alone are available for the Stroop (e.g., Delis et al., 2001) and Tower Tests (Delis et al., 2001; Culbertson & Zillmer, 2001). Unstratified norms are available for Go/No-go (Dubois, Slachevsky, Litvan, & Pillon, 2000) and the Hayling Sentence Completion tests

Table 31.1 Comparison of Commonly Used Tests of Executive Functions

Neuropsychological Test	Normative Data Stratified By	Neuroanatomical Correlates	Links to Functional Outcome
Trail Making Test	Age, Education	Dorsolateral prefrontal cortex	Activities of Daily Living
Verbal Fluency	Age, Education	Frontal, temporal, parietal lobes	Activities of Daily Living
Stroop Test	Age	Dorsolateral and dorsomedial prefrontal cortex	Treatment Outcome Measures*
Card Sorting Tests	Age, Education	Dorsolateral prefrontal and parietal cortices	Need for Supervision, Functional Status at Hospital Discharge
Hayling Sentence Completion	Unstratified Separate norms for older adults	Frontal lobes	Caregiver Questionnaire of Functional Outcome
Tower Tests	Age	Frontal and parietal lobes.	None
Behavioral Assessment of Dysexecutive Function	Unstratified, No Scaled Scores for Subtests	Non-specific Brain Damage	+ Caregiver Questionnaire of Functional Outcome
Go/No Go Test	Unstratified	Ventral prefrontal cortex	Everyday Action Slips

Summary of neuropsychological tests of frontal lobe function in terms of the availability of appropriate norms, neuro-anatomical correlates of task performance, and correlations with measures of functional outcome. * in Modified versions of the Stroop Task; + inconsistent finding.

(Burgess & Shallice, 1997). For the Hayling, norms have been collected separately for older adults (Bielak et al., 2006). For cognitive estimates tests, norms for adults (Axelrod & Millis, 1994) and older adults (Gillespie, Evans, Gardener, & Bowen, 2002) are available.

Brain regions involved in tests

Not all of the tests have specific neuroanatomical correlates, and not all are sensitive to TBI or ventral frontal damage. There is evidence indicating no specific association between frontal damage and performance on cognitive estimates tests (Taylor & O'Carroll, 1995). Tower tests and card sorting tests have frontal *and* parietal lobe involvement, and verbal fluency tests are associated with broad networks including the frontal, temporal and parietal lobes (e.g., Baldo, Schwartz, Wilkins, & Dronkers, 2006; Barcelo, 2001). Neuroimaging and patient studies of the Stroop test suggest it is associated with superior medial frontal and inferior lateral frontal regions rather than ventral frontal cortex proper (e.g., Stuss, et al., 2001; Demakis, 2004). Patient studies of Trails A & B show that completion time on Trails B, not errors, seems to be the most sensitive measure, but even that is sensitive to damage in dorsolateral prefrontal cortex rather than ventral frontal cortex (Stuss, et al., 2001; Demakis, 2004). Several studies show sensitivity to frontal damage on most but not all subtests of the D-KEFS (e.g., Delis, Kramer, Kaplan, & Holdnack, 2004; Keil, Baldo, Kaplan, Kramer, & Delis, 2005; McDonald, Delis, Norman, Tecoma, & Iragui, 2005), and the Verbal Fluency and Category Switching subtests seem to be sensitive to TBI, with mixed results for the Design Fluency subtest (Strong Tiesma, & Donders, 2010; Varney et al., 1996) and ventral frontal damage (Boone et al., 1999). On the more positive side, the Hayling Sentence Completion Test is associated with damage to the frontal lobes generally rather than specifically ventral damage (Burgess & Shallice, 1997), but it is one of the executive tests most sensitive to TBI[i] (Ponsford et al., 2008). Poor performance on Go/No-go tests is associated with TBI and damage to the ventral frontal cortex (e.g., Gagnon, Bouchard, Rainville, Lecours, & St-Amand, 2006; Robertson et al., 1997).

Links to real-world outcomes

The most notable gap in the development of many of these executive tests is the absence of studies linking the tests with real-world functional outcomes. By functional outcome, we mean some measure of the patient's adjustment in daily life, for example, assessing the ability to drive, make friends, hold a job, or assessing real-world behavioral problems. Test manuals rarely include studies investigating these properties of the tests, in spite of how crucial such information is for clinicians. For some tests, researchers have established such links, and we hope that people developing tests in the future will investigate real-world correlates of poor test performance as a routine and necessary part of test development. To our knowledge, there are no studies establishing a link between performance on tower tests or cognitive estimates tests and real-world functioning. Only modified, treatment-specific versions of the Stroop task have been associated with treatment outcomes (Carpenter, Schreiber, Church, & McDowell, 2006; Carter, Bulik, McIntosh, & Joyce, 2000). The Trail-Making and Verbal Fluency tests have been linked to the ability to perform activities of daily living in older adults (Cahn-Weiner, Boyle, & Malloy, 2002). The Wisconsin Card Sorting Test has been linked to the need for supervision and to employment status (Benge, Caroselli, & Temple, 2007; Greve, Bianchini, Hartley, & Adams, 1999; Moritz, et al., 2005). The Hayling test correlates with patients' functional status as reported by a caregiver in a structured interview (Odhuba, van den Broek, & Johns, 2005), and the Go/No-Go task has been linked to everyday action slips (Robertson, et al., 1997).

Linking test performance to functional outcome is perhaps the most important of all aspects of test development. While the absence of norms may necessitate qualitative evaluations of test performance, and a lack of anatomical specificity may mean that corroborative neuroimaging is required for lesion-localization, an absence of a relationship between task performance and patients' real world functioning makes the value of the test questionable. When clinicians or researchers use tests of executive functions that are insensitive to ventral frontal damage or TBI, they risk failing to identify such patients' real lack of competency, or failing to find associations that might be there if more appropriate tests were used. Patients with brain injuries may be denied disability benefits if the cognitive tests used do not capture their particular difficulties. Thus, we strongly encourage clinicians and researchers to use only those executive tests most likely to be sensitive to TBI and/or ventral frontal damage with such patients.

Finally, when clinicians and researchers limit assessment of patients with ventral frontal damage or TBI to assessment only of cognitive, executive functions, they may miss one of the most important areas of disability. The limitation to cognitive assessments has serious, real-world consequences. Patients whose deficits are more social and emotional than cognitive may be denied benefits, and in some cases, they may even be accused of "malingering" because the way in which they were tested does not capture their disability (e.g., Eslinger & Damasio, 1985). Thus, more widespread use of objective measures of social competence is necessary for patients to be treated appropriately.

Performance Measures of Social Competencies in Patients with Ventral Frontal Damage and TBI

As with the assessment of executive functions (Gioia & Isquith, 2004), it will be necessary to measure multiple abilities in order to accurately assess a person's social competence. In the following section, we review some of the tasks developed for this purpose, and evaluate the clinical utility of these tests according to two criteria of central importance in neuropsychological test development (Ardila, Ostrosky-Solis, & Bernal, 2006): whether the tasks are sensitive to the difficulties present in neurological patients who present with social difficulties, specifically, ventral frontal damage or TBI, and whether performance on these tasks has been associated with real-world social functioning (Burgess et al., 2006). Our purpose here is to identify the measures that are most useful for assessments of social competencies from those that are currently available.

Theory of Mind Tasks in Patients with Ventral Frontal Damage and TBI

Several researchers have looked at theory of mind (ToM) in patients with ventral frontal damage, with the idea that deficits in ToM might underlie the patients' social difficulties. The term "theory of mind" suffers from many of the same conceptual problems as the term "executive function": 1) in practice, in the field of neuropsychology, it refers to a set of abilities rather than a unitary ability; 2) a variety of tasks are used to test it; 3) not all of these tasks measure the same ability; and 4) not everyone agrees that ToM is a distinct cognitive module (e.g., Stone & Gerrans, 2006). Furthermore, different groups of researchers use the term to mean different things. In the social neuroscience literature, ToM has often been construed broadly as "the ability to infer others' mental states" (Stone et al., 2003; Bibby & McDonald, 2005; Shamay-Tsoory & Aharon-Peretz, 2007; Shamay-Tsoory, Tomer, Berger, Goldsher, & Aharon-Peretz, 2005; Shamay-Tsoory, Tomer, Berger, & Aharon-Peretz, 2003; Stone, 2007). "Mental states" might include intentions, thoughts, beliefs, emotions, focus of attention, and attitudes. Within developmental and cognitive psychology, however, ToM has a more narrow usage, referring *only* to the ability to do metarepresentation, that is, the ability to understand that mental states of knowledge and belief represent the world, and thus that such mental states can be mistaken (e.g., Baron-Cohen, Leslie, & Frith, 1985; Saxe, Carey, & Kanwisher, 2004; Stone & Gerrans, 2006). In the developmental/cognitive psychology view, "theory of mind" means *only* inferring others' knowledge and beliefs, and specifically excludes inferences about affective mental states (Leslie & Frith, 1990). As detailed below, there is little evidence that patients with ventral frontal damage are specifically impaired in belief understanding and metarepresentation. Their difficulties instead seem to be with understanding others' intentions and feelings.

The tasks that different researchers use to assess ToM demonstrate differences in how they use the term. With a narrow definition of ToM, as in the developmental/cognitive psychology view, the only valid task is a false belief task (see details below), in which the researcher tests whether the participant can infer when someone else's belief state is mistaken. In contrast, with the broader definition of ToM used in most social neuroscience research, tasks examining inferences about intention, attention, sarcasm, empathy, as well as false beliefs have all been used as measures of ToM (Stone, 2007; Stone & Gerrans, 2006). These tasks may involve listening to or seeing brief stories, cartoons, or pictures, and then inferring characters' intentions, feelings, focus of attention, and beliefs, or recognizing when something awkward has been said. Several different tests, besides false belief tests, are used for testing the understanding of others' mental states (see Table 31.2), and we will discuss each one in more detail below. If ToM is more broadly defined to include inferences about mental states such as intentions, feelings, and focus of attention, patients with ventral frontal damage and TBI can be shown to have ToM deficits.

False Belief Tasks-Understanding of Knowledge and Belief

Description of the Task

False belief tasks ask participants to make an inference about what a story character would think or

Table 31.2 Summary of tests of theory of mind in terms of social competences measured, sensitivity to ventral frontal damage or TBI, and correlations with measures of functional outcome.

Name of Test	Social Competences Measured	Test Performance Affected by TBI or Frontal Damage?	Links to Functional Outcome
False belief	Inferring contents of others' knowledge and beliefs	No	No*
Charlie & the Chocolates (Cognitive Version)	Inferring intentions or language reference from eye gaze	Maybe ventral frontal damage from FTD**	Not tested
Charlie & the Chocolates (Affective Version)	Inferring desires from eye gaze	No	Not tested
Reading the Mind in the Eyes-Original Version	Inferring cognitive & affective mental states from eyes	Ventral frontal damage from FTD	No
Happé's Strange Stories (& variants)	Inferring thoughts, beliefs, intentions	Inconsistent results, maybe ventromedial frontal damage	Not tested
Strange Stories-Affective Version	Inferring feelings	No	Not tested
Sarcasm/Irony	Detecting sarcasm or irony by inferring intentions and/or feelings	TBI, ventral frontal damage	Not tested
Faux Pas Recognition	Inferring beliefs, intentions, feelings	TBI, ventral frontal damage	Neuropsychiatric Index Scores (NPI), & maybe Neuropsychology Behavior & Affect Profile
Cartoon tests	Inferring beliefs, intentions	Inconsistent results	No

* Only second-order false belief tasks were related to Neuropsychiatric Index Scores, not first-order false belief; thus the correlation could result from the working memory demands of second-order tasks.
** FTD = frontotemporal dementia. Unknown whether FTD patients did poorly on this test because of social competence deficits or cognitive inhibitory deficits—no control condition run.

believe in a situation in which the story character's belief could be mistaken. A common type of false belief task is a "location-change" task, in which a story character puts an object away, say in a drawer, and then leaves the room. Another character moves the object when the first cannot see, and later the first character comes back into the room. The key question is where the first character now thinks the object is, or where she will look for the object. The methods involve either showing the participant the story in pictures, reading it to them, or having them read the story. Then participants answer questions about the character's belief, as well as control questions testing for memory, comprehension, and (in some cases) inferential abilities (e.g., Stone et al., 1998).

There are also different "orders" of false belief tests. In a first-order false belief test, one is simply asked what the first character thinks or believes, testing understanding of, say, "Maria thinks that [X is true]." In a second-order task, another level of embedding is added, testing understanding of, say, "Jose thinks that Maria thinks that [X is true]." For example, if Maria put an object away and left the room, the story might depict her peeking back through a keyhole and seeing Jose move the object to another location. In that case, Maria would not hold a false belief about the object, but Jose would hold a false belief about Maria's belief, thinking that she didn't know where it was moved to (Baron-Cohen, 1995). This process can be extended to further levels of embedding. A third-order task would test understanding of statements such as "Katrin thinks that Alex believes that Katrin does not know that Alex is having an affair." Higher orders are possible, but after three levels of embedding, the working memory demands of parsing the embedded clauses make the task extremely difficult. It has not been established that second- or third-order false belief tests truly test a greater level of ability to infer *mental states*; instead, they may simply add greater linguistic and working memory demands to the first-order task (Stone, 2007).

Relationship to Ventral Frontal Damage and TBI

Results on frontal patients' performance on false belief tasks are mixed, and there is a good methodological reason for these mixed results. Sound methodology requires controlling for other, non-ToM factors involved in performance on ToM tasks (Bibby & McDonald, 2005; Stone, 2005; Stone, et al., 1998). ToM tasks require not only an intact capacity to metarepresent beliefs, but also an intact ability to make inferences, intact working memory, and inhibition of one's own belief state or personal preference to determine someone else's belief state or preference (Carlson & Moses, 2001; Henry, Phillips, Crawford, Ietswaart, & Summers, 2006; Stone, 2005; Stone et al., 1998; Stone & Gerrans, 2006).

Where the working memory demands of false belief tasks have been controlled for, for instance by placing pictures depicting the sequence of events in front of the participant throughout the session, deficits on false belief tasks are not always evident (Bibby & McDonald, 2005; Gregory, Lough, Stone, Erzinclioglu, Martin, Baron-Cohen, & Hodges, 2002; Muller, Simion, Reviriego, Galera, Mazaux, Barat, & Joseph, 2010; Stone et al., 1998). Stone et al. (1998) found that patients with orbitofrontal damage were at ceiling on false belief tasks on all conditions, and that patients with dorsolateral frontal damage had no deficits when the working memory demands were lowered. Gregory et al. (2002) found that patients with ventral frontal atrophy from frontotemporal dementia performed best on first-order false belief tasks across three different ToM tasks. Stone and Baron-Cohen tested 5 patients with ventral frontal damage on first-, second- and third-order false belief tasks with control tasks requiring first-, second- and third-order non-mentalistic inferences, and found that the patients were not specifically impaired on the false belief tasks compared to the control tasks, though higher orders of embedding were more difficult on both types of task (Stone, 2007). Bibby and McDonald (2005) tested whether TBI patients could understand false beliefs, controlling for working memory with Digit Span (backwards), and found no evidence for specific deficits on these tasks in the patient group.

Failing to control for working memory demands might include using video versions of the tasks, or versions where the action is acted out in some other way, so that the patient has to rely on working memory to keep track of what happened when and to whom. Where the working memory demands have *not* been controlled for, some studies have found deficits on false belief tasks (Stuss, 2001; Fernandez-Duque, Baird, & Black, 2008), and others have not (Shamay-Tsoory & Aharon-Peretz, 2007; Shamay-Tsoory, Tomer, et al., 2005; Snodgrass & Knott, 2006). Shamay-Tsoory, Tomer, et al. (2005) used second-order false belief tasks, and found that patients with ventromedial frontal lesions had no difficulty with these tasks.

Thus, for false belief tasks, which narrowly test for understanding of others' knowledge and belief states, there is scant evidence that patients with frontal lobe damage or TBI have deficits (Stone & Gerrans, 2006). In contrast, patients with posterior lesions in the temporal-parietal junction have specific difficulty with false belief tasks and other tests of metarepresentation, controlling for language, working memory, and inhibitory task demands (Apperly, Samson, Chiavarino, Bickerton, & Humphreys, 2007; Apperly, Samson, Chiavarino, & Humphreys, 2004; Apperly, Samson, & Humphreys, 2005).

Links to Functional Outcome

In frontotemporal dementia patients, Gregory et al. (2002) measured behavioral disturbance and functional problems using the Neuropsychiatric Index (NPI), an index of behavioral problems common in dementia patients, such as problems with inhibition, motivation, and aggression (Cummings et al., 1994). First-order false belief tasks were not related to NPI scores, but second-order false belief tasks did predict NPI scores. It is possible that second-order false belief scores reflected working memory deficits rather than ToM deficits, because of the memory load involved in parsing embedded clauses in higher-order false belief tasks (Gregory et al., 2002). To our knowledge, no other researchers have investigated the relationship between false belief understanding and patient's functioning.

The Charlie and the Chocolates Test–Inferences About Intention and Eye Gaze

Description of the Task

This test, originally designed for children who are too young to pass false belief tests, investigates whether participants can determine desire for, intention towards, or attention to an object from the eye-gaze direction of a cartoon character (Baron-Cohen, 1995). Typically, the response is chosen from four options. A cartoon character in the center of the display, "Charlie," looks at one of four objects arrayed around him. The participant is asked, "Which one does Charlie want?" or "Which one will Charlie take?" Young children also use adults' direction of eye gaze to determine which object an unfamiliar word refers to, so in this task, if the stimuli are meaningless shapes, the experimenter can ask a question about which shape Charlie is referring to with a novel nonsense word when he looks at it, by asking, for example, "Which one does Charlie say is the bleb?" (Baron-Cohen, 1995).

Shamay-Tsoory and Aharon-Peretz (2007) created "cognitive" and "affective" versions of this task. A "cognitive" item showed the character looking at an object, and asked something like, "Yoni is thinking of _________" (which one)? An "affective item would ask something like, "Yoni loves ________" (which one)? They also created second-order versions of the items that probed understanding of a character thinking about a toy that another character likes, or liking/not liking a toy that another character likes.

Relationship to Ventral Frontal Damage and TBI
In addition to testing the ability to infer desire or intention from eye gaze, the Charlie and the Chocolates task has significant inhibitory demands. In order to tell the experimenter that the cartoon character intends to, say, take a particular chocolate bar he is looking at, the participant must suppress her desire for her own preferred chocolate bar (Stone, 2005). Thus, although Snowden and colleagues (2003) found that frontotemporal dementia patients were impaired on the task, it is difficult to know whether the impairment was due to deficits in inhibition or in mental state inference.

Shamay-Tsoory and Aharon-Peretz (2007) gave their version of this task to three groups of patients, one group with dorsolateral frontal lesions, one with ventromedial frontal lesions (including some lesions that extended back to temporal cortex), and one with posterior lesions, as well as age-matched healthy controls. No group differences were evident on the basic version of the task, but in the second-order condition, patients with ventromedial damage were significantly impaired relative to the healthy controls. However, no significant differences were reported between the group with ventromedial damage, and those with dorsolateral frontal or posterior damage. Patients with left frontal lesions (whether ventral or dorsolateral) scored significantly lower on the affective items on this task compared to the cognitive items. Thus, evidence that this task is sensitive and specific to ventral frontal damage is not strong.

Relationship to functional outcome
To our knowledge, no one has yet investigated the relationship between this task and behavioral problems or adjustment in patients.

The Reading the Mind in the Eyes Test—Original Version

Description of the Task
This test is often used as a ToM test (Gregory et al., 2002; Henry, Phillips, Crawford, Ietswaart, & Summers, 2006; Milders, Fuchs, & Crawford, 2003; Stone et al., 2003; Torralva et al., 2007). Some confusion in the literature results from there being two versions of the test. The *original version* of the test (Baron-Cohen et al., 1997) includes not only 17 items asking about subtle emotional states, but also 8 items asking about more cognitive mental states—intention or focus of attention (e.g., "noticing you/ignoring you," "observing/daydreaming," Stone et al., 2003). The original version also had only two response choices, making it more difficult to distinguish participants' performance from chance. The *revised version* (Reading the Mind in the Eyes-R, Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) eliminates all items that ask about focus of attention or intention, and has items only about subtle emotional states. It also has four response choices instead of two. Because the revised version asks only for inferences about emotional states, researchers categorize it as a measure of emotion recognition, rather than a ToM task. Emotion recognition is not considered to be ToM by many researchers, because it is more automatic than inferences about beliefs, knowledge, or attention, develops earlier, and does not require the same kinds of representations (Leslie & Frith, 1990; Stone, 2003).

Relationship to Ventral Frontal Damage and TBI
In Gregory et al's (2002) study, using the original version of the test, patients with ventral frontal atrophy from frontotemporal dementia had deficits on both affective and nonaffective items compared to healthy controls and patients with Alzheimer's disease. Reading the Mind in the Eyes did not correlate with any other ToM tasks in this study,

neither first- and second-order false belief, nor Faux Pas Recognition (described below).

Milders, Fuchs, and Crawford (2003) and Henry et al. (2006) found that patients with TBI were impaired on the revised emotion-recognition version of the task, and Torralva et al. (2007) found that frontotemporal dementia patients were also impaired on the revised task. Although all authors used the phrase "theory of mind" in the titles of their papers, they used the *revised* version of the task, and thus these patients may have had deficits in emotion-recognition rather than deficits in other kinds of mental state inference.

Links to Functional Outcome

In frontotemporal dementia patients, Gregory et al. (2002) found no relationship between NPI scores as a measure of behavioral disturbance, and scores on the original version of Reading the Mind in the Eyes. To our knowledge, no one else has looked at the association between the original version of the Eyes task and behavioral outcomes for patients with ventral frontal damage or TBI.

Happé's Strange Stories Test and Variants–Mixed Mental State Inferences

Description of the Task

Some story-based tasks are not specific to particular kinds of inferences about others' internal states, such as belief, but instead look at participants' ability to infer several mental states from a verbal story, that is, a story characters' thoughts, feelings, and intentions (Channon, Pellijeff, & Rule, 2005; Happé, 1994; Shamay-Tsoory & Aharon-Peretz, 2007; Shamay-Tsoory, Tomer, & Aharon-Peretz, 2005a). In Happé's Strange Stories test (1994), participants read a brief story in which a character does something, such as a spy telling a lie to deceive his interrogators, or a person telling a white lie about how nice someone's awful new haircut looks. (For examples, see pp. 12–13 in Gallagher et al., 2000.) Questions following the story probe whether the participant understood the story character's intentions (e.g., Why did the person say the haircut looked good?), beliefs, or feelings. Control stories and questions about those stories require non-mentalistic inferences, for example, inferences about physical processes.

Shamay-Tsoory et al. (2007) created a version with brief stories that asked either about what a story character thinks about another character's *beliefs* (second-order false belief) or what a story character thinks about how another character *feels*, which they called second-order affective ToM, and thus they could compare what they called "cognitive" and "affective" ToM.

Relationship to Ventral Frontal Damage and TBI

Little evidence exists that performance on this task is impaired by ventral frontal damage, specifically. Snowden et al. (2003) found that patients with ventral frontal damage from FTD were not impaired on mental-state stories compared to control stories on this task. Shamay-Tsoory and Aharon-Peretz (2007), on their affective versus cognitive mental states version of the task, found that there were no differences between patients with ventromedial frontal or posterior lesions or controls on the cognitive version, but that ventromedial frontal patients were significantly impaired relative to patients with posterior lesions on affective items.

Patients with TBI have also been tested on versions of this task. Bibby and McDonald (2005) presented TBI patients with a Stories task, controlling for working memory and language demands, but found no deficits specific to the ToM stories as opposed to control stories in patients. Channon, Pellijeff, and Rule (2005) found that TBI patients were not impaired on mentalistic items relative to healthy controls when they had to choose the correct response from four choices, but TBI patients did have selective difficulty interpreting mentalistic actions in the stories compared to physical actions. Bach et al. (2000), in a case study of a TBI patient, found that he performed as well as both older and younger controls. They note his particular strength in making affective inferences about story characters' feelings. Although their findings are of limited use because they did not compare patients to controls, Bach and David (2006) found that performance on the task predicted TBI patients' social self-awareness. Social self awareness was measured by self-other rating discrepancies on the Patient Competency Rating Scale, a scale measuring behavioral problems and how well a patient can manage independent living.

For reported results on tasks of this type to make sense, researchers must report not just a total score for the task, but also separate scores for each type of mental state asked about, for example, a "feelings inference score," an "intentions inference score," a "beliefs inference score." Because these tasks assess the understanding of several kinds of mental states, a total score is difficult to interpret. A patient could be impaired in inferring others' intentions, for example, but not impaired in inferring feelings or vice versa. Indeed, people with TBI and people with ventral frontal damage seem to be more impaired in inferring intentions or feelings than they are in inferring others' false beliefs (Stone, 2005). As further evidence of dissociability in these abilities, evidence suggests that emotional perspective-taking is associated with ventral frontal activation, whereas nonemotional perspective-taking is not (Hynes, Baird, & Grafton, 2006). Thus, it would be useful to have results on these tasks reported by type of mental state inference.

There is only one study with clear evidence showing that tasks of this type are sensitive to ventral frontal damage or TBI (Shamay-Tsoory & Aharon-Peretz, 2007), and several studies showing that it is not (Bach, et al., 2000; Bibby & McDonald, 2005; Snowden et al., 2003). We can make sense of these different findings by considering that Shamay-Tsoory and Aharon-Peretz (2007) make distinctions between type of mental state inference in reporting their results. The patients in Shamay-Tsoory and Aharon-Peretz (2007) were required to make either cognitive or affective inferences about others' mental states, and the demonstrated deficit was only in affective inferences. Thus, the type of mental state (feeling, belief, intention) about which patients make inferences is crucial to interpreting the patients' scores or group differences. We encourage other researchers to report results on these tasks as a "feelings inference score," an "intentions inference score," a "beliefs inference score," not just a total score, so that the type of inference that is difficult for the patient is clear.

Links to Functional Outcome

Thus far, there are no indications that performance on this task relates to patients' functional outcomes, though little research has been done investigating that question. Bach and David (2006) found no significant difference in performance on Happé's Strange Stories test between "behaviorally disturbed" and "non-behaviorally disturbed participants." Behavioral disturbance was operationalized as relatives' ratings of the patients on the Patient Competency Rating Scale, a measure of behavioral problems and how well a patient can manage independent living. The absence of a strong relationship between these tasks and measures of functional outcome in TBI patients is consistent with the fact that patients with TBI are often able to perform well on the task.

Detection of Sarcasm/Irony Tasks

Description of the Tasks

These tasks are quite similar to Happé's Strange Stories task, but with the items restricted to understanding story characters' use of sarcasm (also called irony in some studies), that is, saying the opposite of what they mean. For example, it is sarcastic to say, when someone has clumsily dropped something, "You're so graceful" or "Why don't you go into neurosurgery?" The participant reads a story, and is asked why someone said what they said, when the utterance was sarcastic, or what someone meant by such an utterance (Channon, et al., 2005; Channon, et al., 2007; McDonald & Pearce, 1996; Shamay-Tsoory & Aharon-Peretz, 2007; Shamay-Tsoory, Tomer, & Aharon-Peretz, 2005; Shamay-Tsoory, Tomer, Berger, Goldsher, & Aharon-Peretz, 2005). Control stories may contain a sincere utterance. The stories are presented in writing, so that tone-of-voice cues do not give away when a character is being sarcastic. Sarcasm comprehension may tap into an understanding of others' intentions, and the social context, because the participant has to understand the speaker's true intention, separate from the literal content of the speaker's statement. An advantage of these tasks over the Strange Stories tasks is that sarcasm-comprehension tasks test understanding of intentions, rather than many different types of mental states.

Relationship to Ventral Frontal Damage and TBI

Several studies have demonstrated that this task is sensitive to ventral frontal damage and TBI. Patients with TBI are impaired in understanding sarcasm as opposed to sincere statements, relative to healthy controls (Channon et al., 2005; McDonald & Pearce, 1996). Patients with ventral frontal lesions are also impaired in understanding sarcasm, but not sincere statements, compared to patients with posterior lesions, dorsolateral frontal lesions, or healthy controls (Shamay-Tsoory, Tomer, & Aharon-Peretz, 2005; Shamay-Tsoory, Tomer, Berger, et al., 2005). There was no significant relationship between sarcasm-comprehension deficits and frontal or posterior lesion size in another study (Shamay-Tsoory et al., 2005b) Kosmidis et al. (2008) found patients with frontotemporal dementia were impaired at using paralinguistic cues to detect sarcasm or lies, but could perform well when more verbal cues indicating sarcasm were given. Thus, many studies confirm that this task differentiates people with TBI from healthy controls, and people with ventral frontal damage from those with dorsolateral frontal lesions, posterior damage, and healthy controls.

Links to Functional Outcome

No studies, to our knowledge, have investigated the relationship of performance on sarcasm detection tasks to patients' behavioral outcomes or ability to engage in activities of daily living. Shamay-Tsoory, Tomer, Berger, et al.(2005), however, did find that greater depression, as indicated by scores on the Beck Depression Inventory, was a strong predictor of lower sarcasm-comprehension scores, though the difference between ventral frontal patients and posterior lesion and healthy control groups could not be attributed to depression scores. This finding implies that the aspects of impaired social competence measured by sarcasm tasks may contribute to social rejection and depression.

Cartoon Tasks

Description of the Tasks

Cartoon tasks have the advantage of testing mental state inferences without requiring comprehension of a verbal story. They use a small number of visual cartoons that require an inference about a character's feelings, intentions, focus of attention, or beliefs to understand the joke (Gallagher et al., 2000; Happé et al., 1999). Control cartoons require a physical inference to get the joke, for example three (presumably blind) mice are asleep in a bed with three tiny pairs of sunglasses on the nightstand. (For examples, see page 14 in Gallagher et al., 2000.) Participants view each cartoon and explain why it is funny. Responses on each are scored from 0 to 3 points, depending on the relevance and correctness of the answer. Responses can also be scored for how many mental state terms are used in explaining the cartoon. A related task asks participants to look at a pair of cartoons, one of which is funny, the other of which is not, and choose the funny one (Happé et al., 1999). Half of the cartoons require mental state inferences to get the joke, and half do not.

As with the Strange Stories Task, these tasks examine the understanding of several types of mental states, such as intentions, beliefs, or focus of attention. One cartoon is funny because of focus of attention: a man is looking at a piano bench that has crashed onto the sidewalk, and has not noticed the piano hurtling towards him from above. Another is funny because of a character's lack of knowledge/false belief: an astronomer does not realize he has black rings around his eyes because his colleagues have put black charcoal around the eye piece of the telescope he has been looking through. Again, we encourage researchers to report scores broken down by type of mental state inference required (intentions, knowledge, belief, feelings, focus of attention). About two-thirds of the items in the version used by Happé and colleagues (1999), however, do seem to depend on false belief. Thus, a total score on this version of the task can reasonably be interpreted as primarily reflecting false belief understanding.

Relationship to Ventral Frontal Damage and TBI

Attempts to link performance on this task to frontal lobe lesions or TBI have produced inconsistent results. Snowden et al. (2003) found that patients with ventral frontal atrophy from frontotemporal dementia produced fewer mental state verbs in their responses to this task, and made more errors in interpreting mental state cartoons versus control cartoons when compared to patients with Huntington's and to healthy controls. When Bibby and McDonald (2005) controlled for working memory deficits using digits backwards from Digit Span, TBI patients showed a deficit specific to mental state inferences on the cartoon task. Milders et al. (2006) found no deficit specific to mental state inferences in TBI patients relative to neurologically healthy controls with orthopedic injuries on the cartoon task when the patients were tested shortly after injury, but scores for the mentalistic cartoons were correlated with scores on Alternating Fluency, a test of cognitive flexibility in which participants generate words in categories, alternating between three categories. Cartoon task scores were not correlated with severity of TBI (as measured by Glasgow Coma Scale scores). One year later, the same TBI patients showed a significant improvement in performance on the mentalistic cartoons relative to the orthopedic controls. Milders et al. (2008) also used the cartoon task with only mental-state cartoons to test another group of TBI patients. TBI patients were significantly impaired relative to matched controls with only orthopedic injuries both soon after their injuries and at one-year follow-up. Bach and David (2006) found that performance on this task predicted TBI patients' social self-awareness (as measured by self-other rating discrepancies on the Patient Competency Rating Scale), but their study did not compare patients to controls, so they provide no information as to its sensitivity to TBI. They also report that performance on both Happé's Strange Stories and cartoon tasks was "associated with a limited number of executive function tests" (Bach & David, 2006 p. 407), but report neither which tests they used, nor the correlations. Because performance on cartoon-based tasks may be affected by many non-ToM factors (working memory, some executive functions, and perceptual abilities), researchers should partial out other cognitive differences in patient groups. Because results on sensitivity of cartoon-based tasks to ventral frontal damage and TBI are mixed, clinicians may not find these tasks most useful for testing patients' social competencies.

Links to Functional Outcome

The little research that has been done testing the relationship between cartoon task performance and functional outcomes for patients indicates no relationship. Milders et al. (2006) found no relationship between a composite measure consisting of cartoon task performance and Faux Pas Recognition task performance, and informant ratings on the Katz Adjustment Scale, which measures social behavior problems, whether shortly after injury or at one-year follow-up. Bach and David (2006) found no significant difference in performance between TBI participants who were "behaviorally disturbed" and those who were not, with behavioral disturbance measured as relatives' ratings of the patients on the Patient Competency Rating Scale.

Faux Pas Recognition Task

Description of the Task

A faux pas is an awkward or insulting statement made unintentionally. The task involves reading a brief story out loud while the patients read along on their own copy. In the faux pas stories, someone says something awkward or insulting, while in the control stories a minor conflict occurs, but no faux pas (Gregory, et al., 2002; Stone, et al., 1998). The patient has a copy of the story in front of them to reduce any memory demands. Several questions are asked that assess whether the participant understands that something awkward has been said, why it was inappropriate to say it, that it was said unintentionally, and that one character might have felt bad as a result of the faux pas. Control comprehension questions test for general comprehension of story facts, apart from mental state understanding. Although this measure was originally introduced as a measure of ToM (Gregory, et al., 2002; Stone, et al., 1998), it measures multiple abilities: false belief understanding, empathy, inferences about intentions, knowledge of appropriate social behavior, as well as language comprehension. Stone (2000; 2005) has noted that ventral frontal patients typically make three types of errors: 1) *faux pas errors*: failing to detect a faux pas, or a false faux pas identification in the control stories; 2) *intentionality errors*: noticing that something awkward has been said, but stating that it was said intentionally instead of accidentally; or 3) *appropriateness errors*: failing to identify the reason that the comment was inappropriate. As noted in the false belief section above, it seems unlikely that ventral frontal patients cannot track false beliefs, as they generally perform at or close to ceiling on false belief tasks. Their faux pas errors on the Recognition of Faux Pas Test sometimes reflect a difficulty inferring that something hurtful has been said, perhaps because they do not notice the "oohhh!" gut response that most people experience when hearing such stories, because of impaired physiological responsivity caused by TBI (e.g., de Sousa, McDonald, Rushby, Li, Dimoska, & James, 2010). At other times, their errors reflect a difficulty tracking others' intentions, resulting in the misperception that the comment was deliberate (intentionality errors), or a difficulty perceiving what would lead to others' distress (appropriateness errors), resulting in failure to detect the faux pas. Such errors are rarely made by controls without brain damage (Gregory, et al., 2002; Stone, 2000; Stone, et al., 1998).

Interpretation of the Recognition of Faux Pas Test in the literature is made more difficult by differences in how the errors are reported. Researchers do report faux pas errors (see hit rates and correct reject rates in Gregory, et al., 2002), but it is rare for researchers to report differences between intentionality errors and appropriateness errors (but see Stone, et al., 1998). These two types of errors tend to be lumped together into a "composite score" or a "follow-up questions score" (Gregory, et al., 2002; Lough & Hodges, 2002; Milders, et al., 2003; Milders, et al., 2006; Shamay-Tsoory, Tomer, Berger, et al., 2005; Torralva, et al., 2007). Detailed reporting of all responses on the test is important for determining the cause of the failure to detect the faux pas, and it appears, from studies that report information broken down by question type, that patients make appropriateness errors, that is, not understanding why the faux pas was awkward or inappropriate, and intentionality errors, that is, not understanding that the faux pas was unintentional (Stone, et al., 1998; Torralva, et al., 2007).

The faux pas task has been found to be independent of the effects of depression in patients with frontal damage (Shamay-Tsoory, Tomer, Berger, et al., 2005). It has been found to correlate with perseverative errors on the Wisconsin Card Sorting Test, but not with other scores on the Wisconsin, nor with verbal fluency (Gregory, et al., 2002). It also may measure something distinct from emotion-based decision-making, as it did not correlate with performance on the Iowa Gambling Task in frontotemporal dementia patients (Torralva, et al., 2007).

Relationship to Ventral Frontal Damage and TBI

The Recognition of Faux Pas Test has often been used in patients with ventral frontal damage from FTD, TBI, or other causes, and researchers have found that such patients are impaired on recognition of faux pas, but not items testing story comprehension (Gregory, et al., 2002; Lough & Hodges, 2002; Milders, et al., 2003; Milders, et al., 2006; Shamay-Tsoory, Tomer, & Aharon-Peretz, 2005; Stone, et al., 1998; Torralva, et al., 2007). Patients with TBI are more impaired on faux pas detection than either patients with dorsolateral prefrontal cortex lesions, those with more posterior damage, or non-brain-injured controls; they often fail to identify social faux pas, and they erroneously label non-faux pas as faux pas (Milders, et al., 2003; Shamay-Tsoory, Tomer, & Aharon-Peretz, 2005; Stone, et al., 1998). They do not, however, appear to exhibit similar impairments on comprehension of the stories in the task (Gregory, et al., 2002; Milders, et al., 2003; Milders, et al., 2006; Stone, et al., 1998). A longitudinal study showed that patients with TBI were impaired on the Recognition of Faux Pas Test an average of two months post-injury, and remained impaired relative to healthy controls one year later (Milders, et al., 2006). There was some improvement in Faux Pas scores over the year, but this improvement was equivalent in patients and controls. A second longitudinal study looked only at the intentionality question on the Faux Pas test, because that was found to best differentiate patients and controls (Milders et al., 2008). Patients with TBI were significantly impaired on the intention question both soon after TBI and at a one-year follow-up (Milders et al., 2008).

Links to Functional Outcome

Faux pas scores were significantly correlated with behavioral disturbances in frontotemporal dementia patients, as measured by the NPI, ($r = -.64$, Gregory, et al., 2002). Faux pas scores were substantially, but not significantly correlated with behavioral outcomes in patients with TBI ($r = -.61$, Milders, et al., 2003), with behavioral outcomes measured using relatives' ratings on the Neuropsychology Behavior and Affect Profile, a questionnaire rating indifference, social inappropriateness, poor communication pragmatics, depression, and mania. However, neither soon after the occurrence of TBI nor at one-year follow-up did Milders et al. (2008) find a correlation between a composite ToM measure including Faux Pas scores and cartoon task scores, and TBI patients' informant-rated behavioral problems on three different rating scales. In patients with schizophrenia, Faux Pas scores significantly predict community functioning, and are better predictors than are cognitive measures (Pijnenborg, Withaar, Evans, van den Bosch, Timmerman, & Browner, 2009).

Conclusions about ToM Tests in Ventral Frontal and TBI Patients

Of the theory of mind tasks reviewed above, sarcasm detection tasks and the Recognition of Faux Pas Task seem to be the most sensitive to ventral frontal damage and TBI. Both are also correlated with some outcome measures: depression in the case of sarcasm tasks (Shamay-Tsoory, Tomer, Berger, et al., 2005), or behavioral disturbances, in the case of the Recognition of Faux Pas Task (Gregory et al., 2002; Milders et al., 2003, 2008). In contrast, there is no strong evidence that false belief tasks, cartoon tasks, story tasks, the Reading the Mind in the Eyes task, or the Charlie and the Chocolates task are consistently sensitive to ventral frontal damage or TBI, nor do any of these measures show correlations with patient outcomes.

In order for sarcasm detection tasks and the Recognition of Faux Pas Task to be clinically useful, the next step in research must be to develop population norms by age, gender, and ethnicity. Without norms to compare an individual client's score to, clinicians cannot tell whether that person is performing as expected or is impaired. Collecting norms for various cultures and subcultures is essential when a test measures social inferences, because subtle cultural differences can affect the way social situations are interpreted.

Theory of mind tests, however, tap into only one type of social competence. They generally use static stimuli or stories, and as such, are quite different from the demands of a dynamic social interaction, in which information is processed rapidly, online, and comes from multiple input sources, including dynamic facial, postural, and prosodic cues. Accordingly, other researchers have developed video-based social inference tasks that improve upon the ecological validity of ToM tasks. One promising video-based tool has been developed out of research on sarcasm detection.

The Awareness of Social Inference Test (TASIT)

Description of the Task

TASIT requires emotion recognition and lie- and sarcasm- detection from video-taped stimuli of actors engaged in social interactions (McDonald, Flanagan, & Rollins, 2002). The authors propose that the Emotion Evaluation Test represents an improvement over previous emotion-recognition measures because the emotional expressions on TASIT are spontaneous, rather than posed, and the dynamic nature of the stimuli allows for the complexity of real-life emotional expressions, including the natural tendency to regulate or conceal a strongly-felt emotion (McDonald, Flanagan, Rollins, & Kinch, 2003). The Social Inference portions of the task consist of short video clips of actors engaging either in sincere or counter-factual exchanges, that is, sarcasm or lies. The context of the statement indicates whether the speaker's meaning is the opposite of what was said (sarcasm or lying), or is sincere. Responses are scored according to four comprehension questions, probing aspects of intention, belief, and emotion (McDonald, et al., 2002). Questions all have yes/no/don't know responses, and are scored as correct or incorrect. Australian norms are available for all three subtests of TASIT (McDonald, Flanagan, & Rollins, 2001).

Relationship to Ventral Frontal Damage and TBI

TASIT was administered to twenty-one people with TBI, and twenty-one age- gender- and education-matched controls (McDonald, Flanagan, Martin, & Saunders, 2004). All measures of TASIT differentiated people with TBI from healthy controls, whereas people with TBI had no difficulty with comprehension of literal statements in the social inference sections of TASIT.

TASIT performance has also been associated with performance on an emotion-recognition task using photographs, a false-belief task, and a social problem-solving task, showing good convergent validity (McDonald et al., 2006). Measures of verbal and visual memory and working memory correlated with TASIT performance as well, however, suggesting that TASIT relies on basic cognitive abilities as well as socially specific skills (McDonald et al., 2006).

To our knowledge, TASIT has not yet been tested in patients with known ventral frontal damage, rather than just a diagnosis of TBI, or in patients with ventral frontal atrophy from frontotemporal dementia. We would predict it to be useful with such patients.

Links to Functional Outcome

TASIT's relationship with real-life social skills was established by demonstrating an association between TASIT scores and structured ratings of social interactions of the participants with TBI (McDonald et al., 2004). Other research has shown that TASIT performance is associated with duration of post-traumatic amnesia and post-injury employment status (McDonald & Flanagan, 2004), and with communication competence (Watts & Douglas, 2006). One social skills training intervention, however, did not improve TASIT scores (McDonald et al., 2008).

Conclusions

Overall, TASIT represents a promising beginning to the development of clinically useful and well-validated measures of social abilities. Across studies, there was variability in both the level and the quality of difficulties exhibited by people with TBI; some struggled with emotions, others struggled with sarcasm/deception inferences, emphasizing the need to have multi-dimensional assessments of social abilities (McDonald & Flanagan, 2004), as we have with cognitive abilities. Thus, although TASIT samples two or three domains of social inference abilities, it would be useful to have tasks that assess a wider range of social inferences than just emotion recognition, deception, and sarcasm.

Possible Future Directions for Applied Social Neuroscience

Social neuroscience has an opportunity to offer tremendous benefits to neurological patients suffering from social deficits, by providing objective ways to define and measure social competence. Many patients with TBI and/or ventral frontal damage suffer long-term consequences to their well-being because of their social deficits, and new developments in this field can help guide clinicians in designing effective rehabilitation programs to improve social functioning in everyday life. There has been a lag between empirical developments in social neuroscience that generate objective, performance-based measures of social competence and clinicians' making use of these measures when assessing social competence. This lag exists partly because many such measures do not have published norms. Clinicians rely on norms to tell them what the expected score on a test would be for a person of the same age, gender, socioeconomic status, and ethnicity. Of the social measures reviewed above, only The Awareness of Social Inference Test (TASIT) has norms available, for primarily white Australians, though versions of the test are now being created for North American and Dutch clients (McDonald, personal communication, 2010). Clinical assessment of patients with TBI or frontal damage instead relies heavily on cognitive performance measures of executive functions, because norms are readily available, while relying on more qualitative or questionnaire-based measures of social and emotional functioning. Clinicians doing rehabilitation, however, are well aware of the need to address social competences, and some treatment programs for TBI address social behavior particularly (e.g., Dahlberg et al., 2007). Social neuroscientists and neuropsychologists therefore have an opportunity to increase the application of their research by 1) collecting norms on social competence performance measures developed; and 2) in patient studies, including measures of real-world functional outcome, so that clinicians can prioritize tests that predict patients' level of coping in their everyday lives.

The purpose of neuropsychological assessments is to make recommendations about a patient's functional status. If a test is insensitive to TBI or ventral frontal damage and uncorrelated with patient outcomes, we should be asking ourselves, "Should this test be included in assessment batteries?" There is considerable time and cost involved in neuropsychological testing, and patients often find it unpleasant, tiring, and frustrating. Therefore, test selection should be parsimonious and the assessments should produce information that has practical, real-world relevance for the purpose of informing treatment recommendations. For these reasons, we encourage researchers and clinicians to work together to investigate the utility of currently used tests, and produce and use new neuropsychological tests that have broad, stratified normative data, empirically demonstrated neuroanatomical correlates, and empirically established associations with real-world functional difficulties. Tests that do not meet these criteria should be re-evaluated and possibly dropped from neuropsychological assessments.

There are many tests of "theory of mind" in the research literature, such as false belief tests and cartoon ToM tests, for which there is no empirical evidence of sensitivity to ventral frontal damage or TBI. In addition, more data linking performance on ToM tests to actual social performance should be gathered; tests that relate to real-world social functioning are valuable regardless of whether the tests are sensitive to specific regions of brain damage.[ii] Despite these problems, two types of ToM tests do seem promising. TBI and ventral frontal damage do seem to impair performance on the Recognition of Faux Pas Task and Sarcasm/Irony Detection tasks, and there are some data linking these tests to functional outcomes. As an ecologically valid extension of Sarcasm tasks, the TASIT is promising as a clinical measure of some social competencies, with norms, solid validation, and links to real-world social competence. The scope of social competencies that these tests measure, however, are limited.

We encourage researchers and clinicians to work together to produce and use objective performance measures of a wide range of specific social competencies, not just the tests of inferring others' internal states reviewed here, but also, for example, the ability to track the intimacy level of the people one is interacting with before disclosing information, to track relative social status and select behavior appropriately, to monitor reciprocity and fairness in interactions, and to understand and act on conversation partner's needs for turn-taking and relevance.

For patients' and their loved ones' best interests, neuropsychological assessments should be geared towards creating treatment programs that may include 1) education for both the patient and the family about key areas of loss in competencies, 2) adopting strategies to manage any difficulties, and 3) retraining some functions. To improve care of patients with social deficits following TBI and/or ventral frontal damage, rehabilitation programs must have a detailed picture of an individual's strengths and weaknesses in a range of social competencies. The TASIT is already available for clinical use. With further research to collect norms and study how tests are related to everyday outcomes, some of the other social competence tests reviewed here could become available for clinical use in the near future, thus improving the assessment and subsequent treatment of social dysfunction following brain damage. Patients and their families would benefit enormously from such progress in social neuroscience research.

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