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Social Perception in Adults With Parkinson's Disease

Marc D. Pell
McGill University and McGill Centre for Research on Brain, Language, and Music

Laura Monetta
Université Laval

Kathrin Rothermich
McGill University and McGill Centre for Research on Brain, Language, and Music

Sonja A. Kotz
University of Manchester and Max-Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany

Henry S. Cheang
McGill Centre for Research on Brain, Language, and Music

Skye McDonald
University of New South Wales

Objective: Our study assessed how nondemented patients with Parkinson's disease (PD) interpret the affective and mental states of others from spoken language (adopt a "theory of mind") in ecologically valid social contexts. A secondary goal was to examine the relationship between emotion processing, mentalizing, and executive functions in PD during interpersonal communication. ***Method:*** Fifteen adults with PD and 16 healthy adults completed The Awareness of Social Inference Test, a standardized tool comprised of video-taped vignettes of everyday social interactions (McDonald, Flanagan, Rollins, & Kinch, 2003). Individual subtests assessed participants' ability to recognize basic emotions and to infer speaker intentions (sincerity, lies, sarcasm) from verbal and nonverbal cues, and to judge speaker knowledge, beliefs, and feelings. A comprehensive neuropsychological evaluation was also conducted. ***Results:*** Patients with mild-moderate PD were impaired in the ability to infer "enriched" social intentions, such as sarcasm or lies, from nonliteral remarks; in contrast, adults with and without PD showed a similar capacity to recognize emotions and social intentions meant to be literal. In the PD group, difficulties using theory of mind to draw complex social inferences were significantly correlated with limitations in working memory and executive functioning. ***Conclusions:*** In early PD, functional compromise of the frontal-striatal-dorsal system yields impairments in social perception and understanding nonliteral speaker intentions that draw upon cognitive theory of mind. Deficits in social perception in PD are exacerbated by a decline in executive resources, which could hamper the strategic deployment of attention to multiple information sources necessary to infer social intentions.

Keywords: mentalizing, emotion processing, speech communication, executive functions, basal ganglia

Social interactions are regulated by the ability to infer what is going on inside another person's mind (Adolphs, 2009). Humans attempt to explain and predict other people's behavior by adopting a "theory of mind" (Frith & Frith, 2001), or making mental state attributions about the beliefs, desires, and feelings of social partners that guide interpersonal communication (Abu-Akel, 2003). Theory of mind (ToM) or "mentalizing" is a central aspect of social cognition that relies on a widespread brain network, including the medial prefrontal cortex, superior temporal sulcus, anterior paracingulate cortex, temporal poles, and the amygdala (Gallagher & Frith, 2003). Two subcomponents of ToM have been differentiated (Poletti, Enrici, Bonuccelli, & Adenzato, 2011; Shamay-Tsoory et al., 2007): *cognitive* ToM refers to processes for representing knowledge about beliefs (e.g., for differentiating the speaker's knowledge from that of the listener), and *affective* ToM refers to processes for deriving an empathic appreciation of an-

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Marc D. Pell, School of Communication Sciences and Disorders, McGill University, and McGill Centre for Research on Brain, Language, and Music; Laura Monetta, Département de Réadaptation, Université Laval; Kathrin Rothermich, School of Communication Sciences and Disorders, McGill University, and McGill Centre for Research on Brain, Language, and Music; Sonja A. Kotz, School of Psychological Sciences, University of Manchester, and Department of Neuropsychology, Max-Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany; Henry S. Cheang, McGill Centre for Research on Brain, Language, and Music; Skye McDonald, School of Psychology, University of New South Wales.

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Correspondence concerning this article should be addressed to Marc D. Pell, School of Communication Sciences and Disorders, McGill University, 1266 Avenue des Pins Ouest, Montreal (QC), H3G 1A8 Canada. E-mail: marc.pell@mcgill.ca

other's emotional state (Bodden, Dodel, & Kalbe, 2010). Data suggest that cognitive ToM preferably engages the fronto-striatal-dorsal circuitry, whereas affective ToM is mediated by the fronto-striatal-ventral circuitry (Hynes, Baird, & Grafton, 2006; Völlm et al., 2006).

During interpersonal communication, ToM is often critical to interpret the *intended* meanings of a speaker, such as humor, irony, and sarcasm, and to determine when a conversational remark does not represent the truth. Intertwined with ToM and the ability to understand speaker intentions is the ability to integrate a diverse range of socially relevant cues, including verbal information, nonverbal cues conveyed by facial expressions and speech prosody ("tone of voice"), and stored knowledge about people and past events. Given the complexity of social interactions, deficits in ToM, emotion processing, and social inference making have been reported in several clinical populations associated with acquired or neurodevelopmental brain disorders, such as autism, schizophrenia, and traumatic brain injury (see Frith & Happé, 1994, Harrington, Siegert, & McClure, 2005, and Martín-Rodríguez & León-Carrión, 2010, for reviews). Recently, researchers have explored this relationship in patients with neurodegenerative disorders that affect the fronto-striatal circuitry involved in ToM, such as Parkinson's disease (PD; see Elamin, Pender, Hardiman, & Abrahams, 2012, Kemp, Després, Sellal, & Dufour, 2012, and Poletti et al., 2011, for reviews). Although diagnosed by its motor signs (e.g., bradykinesia, resting tremor), it is well accepted that PD is linked to serious nonmotor difficulties, even at early stages in the progression of the disease (Park & Stacy, 2009; Thanvi, Munshi, Vijaykumar, & Lo, 2003), which impact negatively on patients' quality of life (e.g., Santangelo et al., 2012). Typical nonmotor changes affecting (social) cognition in PD include deficits in executive functions such as decision making (Mimura, Oeda & Kawamura, 2006) and working memory (Gabrieli, Singh, Stebbins, & Goetz, 1996; Siegert, Weatherall, Taylor, & Abernethy, 2008), difficulties processing humor and nonverbal emotional expressions (Benke, Bösch, & Andree, 1998; Dara, Monetta, & Pell, 2008; Pell & Leonard, 2003, 2005), problems generating inferences about nonliteral or implied meanings in language (Berg, Bjornram, Hartelius, Laakso, & Johnels, 2003; Holtgraves & McNamara, 2010; Monetta, Cheang, & Pell, 2008), and poor ToM (Mengelberg & Siegert, 2003; Monetta, Grindrod, & Pell, 2009).

For example, Saltzman, Strauss, Hunter, and Archibald (2000) compared ToM abilities in 11 PD patients and eight age-matched controls by testing their comprehension of first- and second-order beliefs in false-belief stories, the ability to attribute mental states to cartoon characters, and to use ToM information while performing hide-and-seek-type tasks. They reported that ToM was impaired in PD patients relative to healthy adults, especially in the false-beliefs task, and that there was a significant association between deficits in ToM and executive functions in the PD group (e.g., performance on a verbal fluency task). Similarly, Monetta et al. (2009) required PD patients to infer first- and second-order beliefs from stories that ended in a sarcastic comment or a lie; they concluded that mild-moderate PD patients have ToM difficulties that contribute to problems interpreting social intentions, especially in the ability to attribute second-order beliefs (i.e., inferring what one character knew or believed about the thoughts of another character). These findings converge with growing data showing that PD patients often fail to fully appreciate the emotional or knowledge states of others (Roca et al., 2010). It is noteworthy that Monetta et al. found that deficits in social perception and ToM were again associated with other cognitive limitations in their PD sample (specifically, reductions in working memory and executive control/verbal fluency), a conclusion that has been arrived at by several research groups (Eddy, Beck, Mitchell, Praamstra & Pall, 2013; Mimura et al., 2006; Pell & Monetta, 2008; Saltzman et al., 2000; Yu et al., 2012).

In another study, Péron et al. (2009) compared cognitive and affective ToM abilities in patients in the early versus late stages of PD, to investigate how different facets of ToM decline as the disease progresses. They found that ToM deficits were present only in late stages of the disease and affected only *cognitive* ToM (the ability to infer social intentions in a "faux pas" recognition task). On the other hand, Bodden et al. (2010) argue that PD patients are impaired in both affective and cognitive ToM, and a recent report by Poletti, Vergallo, Ulivi, Sonnoli, and Bonuccelli (2013) uncovered difficulties with affective ToM in a robust sample of PD patients in the moderate-advanced stages of the disease (this latter study did not evaluate cognitive ToM). Based on current findings, it seems likely that many PD patients experience difficulties with both cognitive *and* affective ToM that impact on interpersonal communication, depending on the stage of the disease and/or presence of other disease-related factors, particularly those that limit executive resource capacity (Pell & Monetta, 2008; Yu & Wu, 2013). A major goal of this study was to illuminate how mild-moderate PD patients interpret social intentions that involve cognitive and emotional mental state attributions, in a novel and more ecological manner that sheds light on the relationship between social perception and the cognitive resource capacity of PD patients in everyday situations and settings.

A shortcoming of current studies is that tasks of emotion recognition, social perception, and ToM in PD have largely based their conclusions on how patients perform when presented only one sensory modality, or stimuli otherwise characterized by a restricted set of cues (e.g., Bodden et al., 2010; Monetta, Cheang, et al., 2008; Péron et al., 2009; Roca et al., 2010; Shamay-Tsoory, Tomer, Berger, & Aharon-Peretz, 2003). Most experiments have presented static images of faces or scenes, isolated written materials, or recorded sentences produced without accompanying visual cues, meaning that many of these mentalizing tasks lack ecological validity (see Achim, Guitton, Jackson, Boutin, & Monetta, 2013, for a review of tasks evaluating ToM and a framework for assessing their ecological validity). Recent data suggest that the artificial separation of sensory modalities and/or communication channels could hamper the ability of PD patients to infer mental states and speaker intentions in laboratory situations, when compared with stimuli that supply enriched, redundant social cues (Paulmann & Pell, 2010). In Paulmann and Pell (2010), adults in the early stages of PD had to identify six basic emotions that were dynamically presented in video clips containing varying degrees of verbal (lexical-semantic), prosodic, and/or facial cues about the speaker's emotion state; emotional information was alternately presented in a single channel or a combination of channels. Although PD patients displayed inferior emotion recognition abilities overall when compared with healthy controls, their performance benefitted systematically with the simultaneous presentation of emotional cues in additional communication channels. Given the probable link between deficits in social perception, ToM, and the cognitive resource capacity of individual patients, Paulmann and Pell's findings emphasize the importance of evaluating these skills using multimodal stimuli that approximate the processing demands of naturalistic, everyday events; such stimuli will better characterize the *functional* nature of social perception deficits in the daily lives of PD patients.

A method that can provide new insights about the ability of PD patients to interpret emotions and social intentions in communication, in the context of rich multimodal cues, is The Awareness of Social Inference Test (TASIT; McDonald, 2012; McDonald, Flanagan, & Rollins, 2002; McDonald, Flanagan, Rollins, & Kinch, 2003). TASIT, which evaluates the ability to interpret verbal and nonverbal signals to render judgments about the emotions and mental state of speakers and their specific meaning in conversations, was specifically developed for use with adult clinical populations. Patients are presented videotaped vignettes, in which professional actors enact common situations and conversations, and then are queried about the emotion of the speaker (Part 1) or their communicative intentions (Parts 2 and 3), which are cued by a range of visual, verbal, and nonverbal cues that typically point to a speaker's intended meaning. Because TASIT evaluates how patients recognize emotions and use ToM to infer the social significance of conversational remarks in everyday situations that approximate the resource demands of natural conversations, this battery can shed new light on how PD affects social perception when task-processing demands are reduced. TASIT has proven to be a highly sensitive measure of these skills in other clinical populations associated with frontal lobe dysfunction, such as adults with traumatic brain injuries (McDonald, 2012; McDonald et al., 2003) or frontotemporal dementia (Kipps, Nestor, Acosta-Cabronero, Arnold, & Hodges, 2009; Rankin et al., 2009). Moreover, TASIT is known to have high ecological validity, as it provides six of the eight sources of information humans use when performing mentalizing judgments in real life, according to Achim et al. (2013).

Thus, the goal of this study was to assess how nondemented PD patients with mild to moderate motor symptoms interpret the affective and mental states of others when confronted with ecologically valid cues and everyday situations as presented in TASIT. Given the observed relationship between deficits in interpersonal communication and cognitive functions in PD (e.g., Pell & Monetta, 2008), a secondary goal was to examine performance on TASIT in relation to neuropsychological variables such as working memory and other indices of "frontal lobe" executive resource capacity. We hypothesized that PD participants would demonstrate poorer accuracy on all parts of TASIT relative to healthy, age-matched control participants, although it is possible that deficits in emotion recognition will be mitigated because of the presence of multimodal stimuli that convey informational redundancy about speaker emotions (Paulmann & Pell, 2010). Based on present literature, the ability to interpret nonliteral meanings in conversation, and to infer speaker intentions that center on ToM knowledge, was expected to be an area of difficulty for PD patients—one that should be exacerbated in individuals with limited working memory and/or mental flexibility to devote to this task (e.g., Monetta et al., 2009; Vachon-Joannette, Tremblay, Langlois, Chantal, & Monetta 2013).

Method

This study was ethically approved by the McGill University Faculty of Medicine Institutional Review Board, in accordance with principles expressed in the Declaration of Helsinki (2008). Informed written consent was obtained from each participant prior to their involvement in the research.

Participants

A total of 31 participants were recruited for the study: 15 adults diagnosed with idiopathic PD (seven female; mean age = 70.1 ± 10.8 years; mean education = 15.4 ± 3.3 years), and 16 age- and education-matched healthy control (HC) participants (seven female; mean age = 69.7 ± 8.9 years; mean education = 15.3 ± 2.6 years). All PD and HC participants were native English speakers living in Montreal, Canada, who were recruited through print advertisements posted in local newspapers and at community centers; the PD patients were also identified from movement disorders clinics at Montreal-area hospitals. An overview of demographic, clinical, and cognitive features of individuals in the PD and HC groups is furnished in Table 1.

For the patients, a diagnosis of idiopathic PD was confirmed by a neurologist on the basis of accepted motor criteria; the mean duration of PD postdiagnosis was 10.6 years (range = 4 to 15 years). Motor disability of individuals within the PD group fell in the mild to moderate severity range (stages 2 to 3.5 on the Hoehn & Yahr, 1967, scale), with motor scores ranging from 16 to 43 on the Unified Parkinson's disease Rating Scale (UPDRS; Fahn, Elton, & Committee, 1987). The motor evaluation and all testing were conducted when PD participants were optimally medicated ("on state") as follows: Levodopa-carbidopa ($n = 8$), dopamine agonists/Mirapex ($n = 4$), MAO-B inhibitor/Selegiline ($n = 3$), COMT inhibitors ($n = 2$), amantadine ($n = 3$), and Permax ($n = 2$). Patients with coexisting neurological or major psychiatric conditions, or history of alcohol abuse, were excluded.

Participants in both groups had normal or corrected-to-normal vision as determined by self-report. A pure-tone audiometric screening conducted prior to testing ensured that all participants had acceptable hearing thresholds at frequencies critical for speech intelligibility (minimum 30 db HL at .5, 1, and 2 kHz). All PD and HC participants were screened for dementia using the Mattis Dementia Rating Scale (Mattis, 1988); all participant scores were greater than 129 (scores less than 122 are indicative of dementia; Mattis, 1988). The two groups did not differ significantly on the dementia scale, $t(29) = -.26$, $p = .79$, *ns*. Depressive symptoms were evaluated using the short form of the Hamilton Depression Inventory (Reynolds & Kobak, 1995), which revealed significantly higher mean depression scores in the PD group, $t(29) = -3.52$, $p = .001$. Five PD participants and one HC participant fell within the "mild" depressive range on this test (individual scores between 8 and 13).

Neuropsychological Testing

To obtain a profile of cognitive functioning, each participant completed a battery of standardized neuropsychological tests,

Table 1
Demographic and Clinical Features of Individuals in the Parkinson's Disease (PD) and Healthy Control (HC) Groups

Variable/Test type	PD (*n* = 15)		HC (*n* = 16)		HC > PD (*p* < .05)
	Mean	*SD*	Mean	*SD*	
Sex (F/M)	7/8		7/9		—
Age (years)	70.9	10.7	70.4	9	*ns*
Education (years)	15.4	3.3	15.3	2.6	*ns*
Disease duration (years)	10.6	3.1	—	—	—
Motor UPDRS	29.9	9.1	—	—	—
Mattis Dementia Rating Scale (/144)	139.3	2.3	139	4.4	*ns*
Hamilton Depression Inventory-SF (/33)	5.6	3.9	1.9	2.2	*p* = .001
Benton Phoneme Discrimination (/30)	27.1	1.9	27.8	1.6	*ns*
Benton Face Recognition (/54)	41.9	5.1	47.7	4.1	*p* < .01
Warrington Recognition Memory Word (/50)	40.9	4.8	40.7	5.6	*ns*
Warrington Recognition Memory Face (/50)	45.5	4.9	47.4	2.9	*ns*
Auditory digit span, forward (/9)	6.9	0.9	7.4	1.8	*ns*
Working memory (words recalled, /42)	26.1	8	36.1	4.4	*p* < .001
Tower of London (total score)	106.2	16	117.7	18.6	*ns*
Verbal fluency task: simple (# words)	15.4	3.4	19.7	9.2	*ns*
Verbal fluency task: alternating (# pairs)	6.7	1.8	8.6	1.8	*p* < .01

Note. ns = not significant; M = male; F = female; UPDRS = Unified Parkinson's Disease Rating Scale.

including measures to estimate frontal lobe function and executive resource availability (e.g., the ability to switch strategies or to inhibit the influence of irrelevant information). All participants completed the following tests: (a) a verbal working memory (listening) span test adapted by Tompkins and colleagues (Tompkins, Bloise, Timko, & Baumgaertner, 1994) from an earlier test of working memory by Daneman and Carpenter (1980), (b) the Color Trail-Making test (D'Elia, Satz, Uchiyama, & White, 1997), (c) the Tower of London test (Culbertson & Zillmer, 2001), (d) the Warrington Recognition Memory test for faces and words (Warrington, 1984), (e) Benton Phoneme Discrimination and Face Recognition subtests (Benton, Hamsher, Varney, & Spreen, 1983), (f) the Forward Digit Span test, and (g) the Semantic Verbal Fluency test: simple (naming animals) and alternating (male names and vegetables). The results from statistical analyses of the various neuropsychological measures indicated that the PD and the HC group performed in a comparable manner on many cognitive and frontal lobe tasks ($p > .05$); significant group differences were found solely for the word recall portion of the verbal working memory task, $t(29) = 4.32$, $p < .001$, the verbal fluency score in the alternating condition, $t(29) = 2.94$, $p = .006$, and the Benton Face Recognition task, $t(29) = -3.47$, $p = .002$. Table 1 summarizes results of the neuropsychological assessment for individuals in each group, emphasizing that most PD patients were relatively high functioning at time of testing.

Materials

All participants completed TASIT (McDonald et al., 2003), comprised of short video clips performed by trained professional (Australian) actors in English. As noted earlier, this tool was designed to assess the ability to perceive social cues presented in a realistic setting. The test contains three separate subtests, as summarized in the following sections:

Emotion evaluation test (Part 1). This test examines the ability to categorize six basic emotions (happy, sad, fear, disgust, surprise, and anger) from verbal and nonverbal cues. Participants viewed 28 video vignettes, each 15 to 60 s in duration, of professional actors portraying one of the six emotions or "neutral" scenes that conveyed no emotion. Each vignette shows either a single actor speaking into a telephone handset or speaking directly at the camera, or two or more actors interacting with one another in everyday situations. For scenes in which two actors were present, subjects were instructed to focus on only one specific actor, that is, the target actor. The text of all scripts performed by the actors was neutral in content. After viewing each video clip, participants were required to choose the emotion category from among the seven labels that best described the emotional state portrayed by the target actor.

Test of social inference (minimal; Part 2). This test evaluates the ability to perceive social inferences and to make judgments about the thoughts and feelings of speakers from their verbal and paralinguistic cues (i.e., facial expressions, prosody). This test consists of 15 short (20 to 60 s) video vignettes, which model a range of everyday conversational exchanges between two or more persons, performed by the same actors from Part 1. Participants must interpret the behavior of a target actor in the vignette. There are three types of exchanges in Part 2: sincere exchanges, simple sarcastic exchanges, and paradoxical sarcastic exchanges (see Table 2 for examples). In the sincere exchanges, the target actor intends her remark to be interpreted literally. In the simple sarcastic exchanges, the intent of the target actors is to communicate a mocking, critical message that is nonliteral (opposite to what is actually said). In the paradoxical sarcastic exchanges, the script itself is paradoxical and can only make sense as a sarcastic exchange. Following each vignette, participants must answer four different types of probe questions (see Table 2):

1. "Do" questions: Participants were asked what one particular character was intending to do to his conversational partner;

Table 2
Examples of Scripts and Probe Questions Corresponding to Vignettes Presented in the Test of Social Inference Part 2 (Minimal) and Part 3 (Enriched)

Part 2 – Sincere or simple sarcasm (enacted either sarcastically or sincerely using only paralinguistic cues)
Ruth: Great movie, wasn't it?
Michael: Oh, yeah, great.
Ruth: I thought it was terrific. I was on the edge of my seat.
Michael: Oh, me too, on the edge of my seat.
Ruth: Well, weren't you surprised by the ending?
Michael: Oh, yeah, the ending was a huge surprise.
Ruth: I thought the actors were very good. I really liked that main girl.
Michael: She was unbelievable, and the guy opposite her—what a performance!
Ruth: It's a shame it's closing. I'd like to see it again.
Michael: Yeah, what a shame. I feel I could see it another dozen times.
Probe questions
Do: Is Michael agreeing with Ruther about the movie?
Say: Does he mean the actors were good?
Think: Does he think the movie was bad?
Feel: Did he enjoy the movie?
Part 2 – Paradoxical sarcasm (script is nonsensical unless one speaker assumed to be insincere)
Gary: Have you got your ticket?
Keith: Nope. I tore it up and threw it away.
Gary: Good. And your passport's safe?
Keith: Sure, I threw that in the bin along with my ticket.
Gary: So, you've got everything.
Probe questions
Do: Is Keith seriously trying to make Gary think he's lost his ticket?
Say: Does Keith mean he has got his ticket and passport?
Think: *By the end of the scene*, does Gary think Keith has his ticket?
Feel: Is Keith grateful that Gary checked about his ticket?
Part 3 – Sarcasm or lie with epilogue/prologue
Prologue
Keith: Did you hear? Frank smashed the boss's car?
Ruth: What! The boss will kill him. That car's his life.
Keith: It's a mess. A total write-off.
Ruth: He'll explode. And Frank's already in his bad books. He'll probably lose his job over this. It's not the first time he's . . . (Frank enters)
Main part of scene (Ruth is either lying or being sarcastic)
Frank: What am I going to do? He'll kill me—or at least fire me.
Ruth: Well he won't be pleased, but I'm sure if you explain he'll understand.
Frank: You know what he's like. I'd better start looking for another job.
Ruth: Oh, come on; you're his star worker. He thinks you're terrific.
Probe questions
Do: Was Ruth trying to make Frank more worried about the boss's reaction?
Say: Was Ruth telling Frank that she thought the boss would understand?
Think: Did Ruth think the boss had a good opinion of Frank?
Feel: Did Ruth feel sorry for Frank?
Part 3 – Sarcasm or lie with visual cues
Tanya (carrying a plate): Cal would like some ice cream.
Mick (busy, not looking at plate): As long as he has eaten all his dinner.
Tanya: Oh, yeah, he's eaten all his dinner, all right.
(Camera shows close-up of nearly full plate—hidden from Mick in "lie" mode but visible to him in "sarcasm" mode)
Mick: I told him to finish everything on his plate.
Tanya: Well, he certainly listened to you.
Probe questions
Do: Is Tanya trying to make Mick believe Cal ate all his dinner?
Say: Does she mean that Cal obeyed Mick?
Think: Does Mick think Cal ate all his dinner?
Feel: Is Tanya hoping Mick will think Cal at his dinner?

Note. From McDonald et al. (2003).

this question assessed whether participants could judge speaker intentions (which often involved second-order ToM judgments).

2. "Say" questions: Participants were asked whether the target character wanted the literal or nonliteral meaning of their message to be believed.

3. "Know" questions: Participants were asked to identify the beliefs and knowledge of the target character regarding the situation; this question probed whether participants could make ToM judgments about the knowledge state of characters.

4. "Feel" questions: Participants were asked to identify the emotion felt by the target character.

Test of social inference (enriched; Part 3). This test evaluates the ability to make social inferences inherent in telling lies or in expressing sarcasm. Similar to Part 2, this test consists of a series of 16 unique video vignettes (each lasting between 15 and 60 s) in which actors are engaged in routine conversations. However, in the "enriched" test, there are no depictions of literal conversations between characters; rather, participants must always uncover the intended, nonliteral meanings of the target actor. Half of the vignettes depict situations in which target characters are being sarcastic, and the remaining vignettes depict situations in which target characters are telling white (or "sympathetic") lies to spare a second character's feelings. In the sarcastic vignettes, all involved characters are aware of the target character's state of mind, whereas in the lie vignettes, the nontarget characters are not. Participants are provided enriched verbal or visual contextual cues to determine the communicative intention of the target actor. For the vignettes containing enriched verbal cues, the target actor verbally expressed his or her true feelings about a second character or situation to a third character, just prior to or after interacting with the second character (i.e., in a short prologue or epilogue, respectively). By contrast, in the vignettes with enriched visual cues, the target actor shows his or her true reaction to a pertinent event nonverbally (and out of view of other characters) prior to or after interacting with other characters. Following each vignette, participants are posed the same series of probe questions described in Part 2 to evaluate their understanding of the target character in reference to "doing," "saying," "knowing," and "feeling" (see Table 2 for examples).

Procedure

Participants were tested in a quiet room in the patient's home or in a laboratory setting during two 1.5-hr sessions (separated by a period of 1 week). Participants completed both neuropsychological and experimental tests during each session; for the experimental tasks, TASIT Parts 1 and 2 were always completed in Session 1 and Part 3 in Session 2. TASIT videos were presented from a wide-screen Toshiba laptop connected to high-quality external speakers for free-field audio output. Participants were encouraged to carefully attend to the vignettes, and following each trial, they responded to questions posed by the examiner about the displayed interactions.

In the Emotion Evaluation Test (Part 1), participants had to decide which of the six basic emotions (or neutral affect) was portrayed in each vignette; emotion labels (response categories) were simultaneously displayed on a sheet of paper placed before them. For the response categories, the original emotion terms "revolting" and "anxious," which were designed for use with Australian participants, were replaced with the respective labels "disgust" and "fear," which are more typical in Canadian speech. After each vignette presented in Parts 2 and 3 (social inference), participants answered the series of four probe questions, posed orally by the examiner, which gauged their interpretation of what the speaker was doing, meaning to say, thinking, and feeling (see McDonald et al., 2002, 2003, for additional examples and full details of test administration). Participants responded to all questions orally without time limitations; answers were recorded by the examiner on a standardized score sheet for later analysis. Participants were questioned after the study as to whether they experienced any difficulties understanding speakers in the vignettes, because of the fact they spoke Australian rather than Canadian English, but no difficulties were reported by individuals in either group.

Results

The mean accuracy of the PD and HC participants on each part of TASIT is summarized in Figure 1. Separate analyses (mixed ANOVAs) were conducted on the accuracy scores for each part as a function of relevant factors. When called for, post hoc analyses were carried out using Tukey's HSD procedure ($p < .05$), and measures of effect size were expressed as partial eta squared (η_p^2).

Emotion Evaluation Test

To understand how participants recognize emotional cues in everyday scenes, a 2 × 7 mixed ANOVA was carried out on the mean proportion of correct responses with the between-subjects factor Group (PD, HC) and the within-subjects factor Emotion (happy, sad, fear, disgust, surprise, anger, neutral). The analysis uncovered a significant main effect of Emotion, $F(6, 174) = 10.72$, $p < .001$, $\eta_p^2 = 0.27$, indicating that participants differed in how well they could recognize particular emotions. Post hoc tests indicated that participants were less accurate in identifying neutral vignettes when compared with the other emotions, and identified surprise significantly better than sadness or anger. There was no significant effect of Group, $F(1, 29) = 0.55$, $p = .46$, *ns*, $\eta_p^2 = 0.019$, or interaction of Group × Emotion, $F(6, 174) = 0.93$, $p = .46$, *ns*, $\eta_p^2 = 0.031$.

Test of Social Inference (Minimal)

To understand whether PD patients could process literal versus nonliteral (sarcastic) meanings in conversation, an initial 2 × 3 mixed ANOVA compared the overall accuracy scores in TASIT Part 2 according to group (PD, HC), with repeated measures on communicative intention of the speaker (sincerity, sarcastic, paradoxically sarcastic). There was no evidence that the groups differed on this task, as no main or interactive effects reached

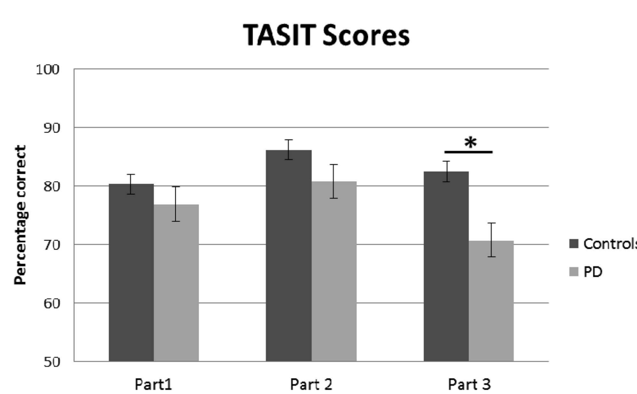

Figure 1. Mean accuracy of participants in the Parkinson's disease (PD) and healthy control groups on each part of The Awareness of Social Inference Test (TASIT) for (a) emotion evaluation (Part 1), (b) social inferences – minimal (Part 2), and (c) social inferences – enriched (Part 3). Error bars represent the standard deviation around the mean.

statistical significance (Group, $F[1, 29] = 1.72$, $p = .20$, $\eta_p^2 = 0.056$; Intention, $F[2, 58] = 1.45$, $p = .24$, $\eta_p^2 = 0.048$; Group × Intention, $F(2, 58) = 0.46$, $p = .62$, $\eta_p^2 = 0.015$; all *ns*).

A subsequent analysis then evaluated whether the groups differed in their ability to correctly answer specific probe questions based on their analysis of tokens in Part 2. A 2 × 4 ANOVA comparing Group (PD, HC) with repeated measures on Question Type (thinking, doing, feeling, saying) yielded a main effect of Question Type, $F(3, 87) = 4.02$, $p = .01$, $\eta_p^2 = 0.122$. Post hoc tests revealed that responses to "thinking" questions ($M = 12.0/15$) were significantly less accurate overall than those to "doing" questions ($M = 12.8$) as well as "feeling" questions ($M = 12.6$), implying that participants found it somewhat harder to infer the knowledge states of characters in Part 2. There was no evidence that this pattern was significantly influenced by the grouping variable (Group main effect, $F[1, 29] = 1.28$, $p = .27$, $\eta_p^2 = 0.042$; Group × Question Type, $F[3, 87] = 0.55$, $p = .63$, $\eta_p^2 = 0.019$; both *ns*).

Test of Social Inference (Enriched)

To determine whether PD patients could infer the meaning of nonliteral remarks in enriched scenarios, a 2 × 2 mixed ANOVA was first run on Group (PD, HC), with repeated measures of communicative Intention (lie, sarcasm). The analysis revealed significant main effects for Intention, $F(1, 29) = 10.89$, $p < .01$, $r = .52$, $\eta_p^2 = 0.273$, and for Group, $F(1, 22) = 8.63$, $p < .01$, $r = .48$, $\eta_p^2 = 0.23$, but no significant interaction of these factors, $F(1, 29) = 0.09$, $\eta_p^2 = 0.003$, *ns*. For the Intention main effect, post hoc comparisons showed that participants detected lies more accurately than sarcasm overall. The Group main effect was explained by the inferior capacity of PD patients to recognize nonliteral intentions when compared with the HC group overall (see Figure 1, right-hand side).

A subsequent 2 (Group) × 4 (Question Type: thinking, doing, feeling, saying) ANOVA performed on the data for individual probe questions in Part 3 revealed a significant main effect for Question Type, $F(3, 87) = 3.17$, $p < .05$, $\eta_p^2 = 0.099$, in addition to the Group main effect already noted, $F(1, 29) = 8.36$, $p < .01$, $r = .47$, $\eta_p^2 = 0.224$, with no significant interaction of Group × Question Type, $F(3, 87) = 0.50$, $p = .69$, $\eta_p^2 = 0.017$, *ns*. Post hoc analysis of Question Type revealed that, contrary to Part 2, responses to "thinking" questions ($M = 13.0/15$) were significantly more accurate on average than those to "doing" ($M = 12.4$), "saying" ($M = 12.1$), and "feeling" ($M = 11.9$) questions. This suggests that all participants found it somewhat easier to correctly judge the knowledge state of characters in Part 3 than speaker intentions and feelings, perhaps owing to the fact that Part 3 provided explicit visual and verbal cues to convey what speakers "know" (McDonald et al., 2003), though this pattern was similar between groups.

Relationship to Background Variables

To examine what factors may have been associated with group differences in the ability to make enriched social inferences, Pearson correlations (two-tailed, $p < .05$) were computed between performance on Part 3 of TASIT (total score) and measures of age (years), education (years), PD duration (years), depression (HDI total score), working memory (words recalled), and a composite score of "frontal lobe functioning" (computed by averaging the standardized distribution of scores for each participant for the Tower of London [total correct], Color Trails Test Part2 [time to completion, inverted], and the two measures of verbal fluency [number of categories achieved, simple and alternating conditions]). For the HC group, there was a significant negative correlation indicating that advancing age was associated with decreased performance on TASIT Part 3 ($r = -0.63$), as well as with reduced frontal lobe composite scores ($r = -0.50$). No other correlations were significant for the HC group. For the PD group (see Figure 2), the ability to make enriched social inferences (Part 3) was strongly associated with increased working memory capacity ($r = .74$) and frontal lobe functioning ($r = .72$), but not PD duration ($r = -0.15$, $p = .60$, *ns*) or depression ($r = -0.14$, $p = .61$, *ns*). A significant negative correlation between age and working memory capacity was also observed in the PD group ($r = -0.67$).

Discussion

Social perception rests on cognitive, emotional, and motivational processes that modulate interpersonal behavior necessary to perform even "simple" tasks, such as to correctly infer the intended meaning of conversational remarks. Given indications that PD affects frontal lobe structures implicated in many social–cognitive processes (e.g., Yu & Wu, 2013), this study investigated how adults with and without PD interpret dynamic and complex, but naturalistic (i.e., ecological valid), stimuli that convey emotional or social meanings using TASIT; this approach allows new insights about the impact of PD on emotion perception, ToM, and the ability to derive social inferences in everyday settings. Our results show that the performance of PD patients only deviated from that of healthy controls on the Enriched Social Inference Test (TASIT Part 3), but not on the Emotion Evaluation or Minimal Social Inference Test (Parts 1 and 2). Moreover, measures of working memory and "frontal lobe" executive capacity in the PD group were significantly associated with their ability to make enriched, social interpretations about the meaning of nonliteral remarks, as evaluated in TASIT Part 3. The relevance of these findings for understanding the scope and progression of social communication deficits in PD is discussed in the next section.

Effects of PD on Emotion Recognition

In daily social interactions, recognizing the *emotions* of conversational partners relies on the ability to decode facial, gestural, vocal, and verbal cues provided by the speaker. In addition to difficulties *expressing* emotions because of motor impairments (Caekebeke, Jennekens-Schinkel, Van der Linden, Buruma, & Roos, 1991; Cheang & Pell, 2007), there is clear evidence that PD impacts negatively on the ability to process and interpret nonverbal cues about emotion from facial expressions and speech prosody, even at early stages of the disease (for reviews, see Gray & Tickle-Degnen, 2010, Pell & Monetta, 2008, and Péron, Dondaine, Le Jeune, Grandjean, & Vérin, 2012). However, virtually all studies to date have presented isolated words, semantically meaningless pseudoutterances, static images of emotional faces, or other types of stimuli that deprive patients of multiple, concurrent fea-

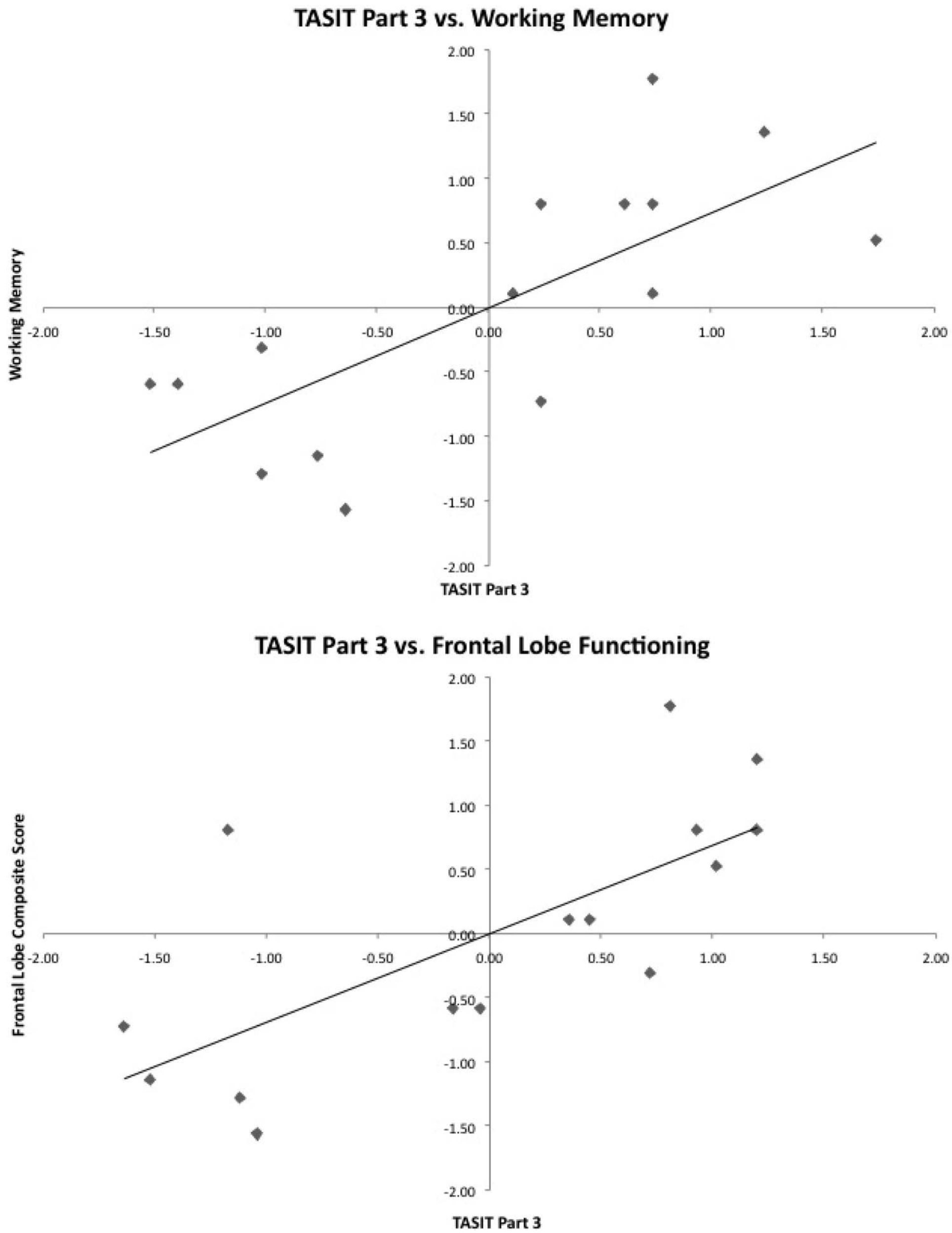

Figure 2. Scatterplots for the Parkinson's disease group (n = 15) showing the relationship between the ability to make enriched social inferences on The Awareness of Social Inference Test (TASIT) Part 3 (total score) and standardized measures of individual (a) working memory (words recalled) and (b) frontal lobe executive capacity (composite score).

tures that are known to enhance emotion processing in natural communication for healthy adults (Collignon et al., 2008; de Gelder & Vroomen, 2000; Paulmann & Pell, 2011). No studies have evaluated emotion recognition in PD when the stimuli are contextualized in everyday circumstances.

Here, we found no evidence that PD patients were inferior to healthy controls in the ability to accurately detect six basic emotions when viewing characters in film vignettes representing everyday situations (e.g., talking on a telephone, a conversation between two adults). Rather, patients displayed similar quantitative and *qualitative* tendencies as healthy adults in the ability to recognize specific emotional expressions, and it was noted that the overall scores of both groups on TASIT Part 1 fall in the "typical" range of performance expected from clinically intact subjects described by McDonald and colleagues (2003). In a related study, Paulmann and Pell (2010) tested emotion recognition in PD by presenting videos containing different combinations of facial, prosodic, and verbal cues. They reported that performance of both PD and HC participants systematically improved as the level of informational redundancy for interpreting emotions increased; these benefits were observed despite the fact that video stimuli, even in the most "enriched" condition of that study, presented only the isolated face of a speaker with congruent verbal and prosodic cues, a situation that is still quite impoverished when compared with everyday communication.

Our finding that the PD group performed normally on the Emotion Evaluation Test of TASIT serves to replicate and extend work of Paulmann and Pell (2010) by demonstrating that many PD patients can harness a converging set of redundant cues, and potentially other forms of supporting context, to render appropriate decisions about a speaker's emotional state. Possibly, the presence of supporting cues across different channels and modalities benefits PD patients because they are less constrained in their *choice* of which cues or strategies to use to decode the affective states of others, and can accord greater weight to specific immediate cues that allow correct inferences about the speaker's emotion state (Kan, Kawamura, Hasegawa, Mochizuki, & Nakamura, 2002; see Achim et al., 2013, for a theoretical framework). Indeed, there are other examples in which PD patients derive cognitive benefits from informational redundancy and/or external cues that help build a stable representation of meanings in memory, with positive effects on behavior (Calleo et al., 2012; Kotz, Gunter, & Wonneberger, 2005). Given that the PD patients tested by Paulmann and Pell (2010) were impaired overall to recognize emotions, whereas the current patients were unimpaired, it seems likely that contextual and situational parameters (e.g., physical setting, etc.), visual cues about posture and gesture, and other "enriched" features of everyday conversations captured by TASIT stimuli are among the crucial sources of information that dictate how well PD patients interpret emotions (and possibly other meanings) in activities of daily living.

Effects of PD on Social Perception

In addition to emotions, social inferences play a critical role in conversations because speakers often communicate meanings that are not literal or readily apparent—what *is intended* is not always literally *said*. Often, the social significance of an utterance is signaled by accompanying facial expressions, tone of voice, gestures, and body language that "point" the listener to the intended, nonliteral meaning of an utterance in its situational context; Parts 2 and 3 of TASIT assessed how well participants could infer literal or nonliteral meanings of remarks that were meant to be sincere, sarcastic, or lies. Our data show that PD patients performed similar to control participants in their ability to differentiate literal (sincere) versus nonliteral (sarcastic) remarks in Part 2 (social inference, minimal); however, they were significantly less accurate than controls on Part 3 when required to infer the precise meaning of nonliteral remarks when speakers were being sarcastic or telling a lie (test of social inference, enriched). On Part 3, difficulties interpreting nonliteral remarks within the PD group were significantly associated with reductions in individual auditory working memory and "frontal lobe" executive capacity, a relationship that has been highlighted by several previous studies of nonliteral language processing in PD (Berg et al., 2003; Holtgraves & McNamara, 2010; McNamara, Stavitsky, Harris, Szent-Imrey, & Durso, 2010; Monetta et al., 2009).

As TASIT Parts 2 and 3 both evaluate the comprehension of social intentions, the fact that PD patients were selectively impaired in Part 3 begs for an explanation. One important difference of the video vignettes in Part 3 is that they presented "enriched" visual or verbal cues to participants when compared with video stimuli in Part 2; this supplementary information regarding the main speaker's knowledge and beliefs, and the extent to which these were shared by the other protagonist, were vital to correctly infer whether speakers were being sarcastic or telling a lie. Thus, it can be said that the comprehension process in Part 3 relies in a more complex manner on the ability to make first- *and* second-order (cognitive) ToM attributions to understand the intention of conversational remarks. Given our pattern of findings, it seems that PD patients in our study exhibited certain deficits adopting ToM and using this knowledge to interpret nonliteral meanings in Part 3 of the study, although they could make less complex judgments, possibly using a heuristic strategy, to differentiate literal versus sarcastic comments. Our results fit with Rankin et al.'s (2009) observation that adults with other forms of neurodegenerative illness and cognitive impairment perform normally when tested on the simpler Part 2 of TASIT (similar to what we observed for PD); they also fit with results of Monetta et al. (2009), who found that PD patients could interpret literal or factual comments at the end of stories but were significantly impaired to judge first- and second-order beliefs to determine when a character was communicating irony or telling a lie (see also Monetta, Grindrod, et al., 2008, for data on linguistic inferencing). More broadly, our data support studies arguing that ToM is vulnerable in PD (Mengelberg & Siegert, 2003; Péron et al., 2009; Poletti et al., 2013; Saltzman et al., 2000; Yu et al., 2012), while demonstrating that ToM deficits have negative consequences on communication and social skills that draw heavily upon the ability to mentalize.

The relationship between social inferencing abilities in Part 3 and the executive resource capacity of PD patients provides further insight into the data. These results argue that many PD patients find it difficult to infer nonliteral meanings, and to use ToM to interpret speaker intentions, because these social-interpretative processes are challenging in cognitive terms and sometimes exceed the executive resources available to individuals with the disease. It is well accepted that many PD patients have fewer "cognitive resources" (broadly defined) to strategically allocate during information processing because of difficulties with prospective memory (Kliegel, Altgassen, Hering, & Rose, 2011), changing mental sets (Cools, Barker, Sahakian, & Robbins, 2001; Mimura et al., 2006; Owen, 2004), combating the effects of mental fatigue (Friedman et al., 2007), and/or effectively deploying working memory (Koerts, Leenders, & Brouwer, 2009). At the same time, the ability to integrate multiple sources of information to infer mental states, and to make social decisions based on these event details, demands a high level of cognitive control (Ganis, Kosslyn, Stose, Thompson, & Yurgelun-Todd, 2003; Linderholm & van den Broek, 2002; McDonald et al., 2003; Virtue, Parrish, & Jung-Beeman, 2008).

Our results add to this literature by showing that reductions in working memory and executive control are highly predictive of difficulties in ToM and social perception in the course of PD, despite the fact that our task approximated the demands of "everyday situations" and that PD patients in our sample were high functioning. Arguably, limitations in working memory and the strategic allocation of attentional resources hampered the ability of PD patients to integrate and *compare* disparate features—that is, verbal, facial and vocal expressions, among other cues—necessary to infer speaker intentions in Part 3, while forming complex mental state attributions based on knowledge of first- and second-order beliefs (Monetta et al., 2009). Because the early effects of dopamine depletion on the frontal cortex are greatest in the dorsolateral fronto-striatal circuits (Kish, Shannak, & Hornykiewicz, 1988)—areas associated with working memory and other forms of mental planning—it is reasonable to conclude that reductions in cognitive resources available for social cognition and ToM occur early and frequently in PD. That is, depending on the processing conditions and associated demands for understanding social intentions, emerging deficits in executive control in PD hold significant potential to impact negatively on emotional processing (Breitenstein, Lancker, Daum, & Waters, 2001) and social-pragmatic skills (Bodden et al., 2010; Eddy et al., 2013; Mimura et al., 2006; Pell & Monetta, 2008; Saltzman et al., 2000; Yu et al., 2012), as is being highlighted by a growing body of work.

The question of how PD affects the brain mechanisms that support cognitive versus affective ToM as the disease unfolds is critical for future work, particularly as ToM abilities share a common neuroanatomical substrate in the dorsolateral prefrontal cortex with many executive functions that decline in PD (Bodden et al., 2010). Comparison of our results across tasks suggests that PD patients can have significant difficulties identifying *mental* states (cognitive ToM) without concomitant deficits appreciating the emotional state of speakers (affective ToM), in line with previous data indicating that cognitive ToM tends to be more problematic in PD (Mengelberg & Siegert, 2003; Monetta et al., 2009; Péron et al., 2009). However, research implies that there is a *progressive* breakdown in ToM capacity in PD, as the disease initially promotes functional deficits affecting dorsolateral prefrontal circuits, followed by ventromedial fronto-striatal pathways (Cools et al., 2001; Kish et al., 1988); this means that deficits in cognitive ToM should dominate at less-advanced stages of the disease, whereas deficits in both cognitive and affective ToM should characterize PD patients at more advanced stages (Poletti et al., 2011, 2013). Although our data are not inconsistent with this view, more direct measures will clearly be needed to elucidate the relationship between PD disease stage, the extent of cognitive decline, and impairments of cognitive versus affective ToM as this literature is developed.

Conclusions

Our results demonstrate that many PD patients have difficulties making mental state attributions necessary to generate inferences about the social intentions of speakers (e.g., in the context of a nonliteral, sarcastic remark), especially when large demands are placed on their cognitive resource capacity during social perception. At the same time, PD patients in the mild-moderate stage of the disease appear to benefit from enriched conditions that provide multiple, overlapping cues for understanding emotions and other social information, independent of emerging difficulties in executive control.

An obvious limitation of our study is that conclusions are based on a small participant sample size; generalizing these results will therefore require new studies, preferably which evaluate social inferencing abilities in new language and cultural contexts. Another limitation is that our current design does not allow us to establish which cues may have been problematic or beneficial for PD patients when rendering judgments about emotions and social intentions; future studies may wish to carefully manipulate the *types* of social cues available to PD patients in the context of ecologically valid stimuli, and the availability of both “immediate” and “stored” information that contributes to mentalizing abilities, according to Achim et al.’s (2013) recent “8-SIF” theoretical framework (or similar model). It may also be useful to determine how empathy is affected as PD advances in relation to measures of social perception; because performing TASIT and similar tasks does not require the *experience* of affect, but rather the *identification* of emotional and mental states, it is unclear whether PD patients experience attenuated sensations of emotions that could alter how they use this information in certain aspects of social decision-making.

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