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Irony comprehension and theory of mind deficits in patients with Parkinson's disease

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ABSTRACT

Many individuals with Parkinson's disease (PD) are known to have difficulties in understanding pragmatic aspects of language. In the present study, a group of eleven non-demented PD patients and eleven healthy control (HC) participants were tested on their ability to interpret communicative intentions underlying verbal irony and lies, as well as on their ability to infer first- and second-order mental states (i.e., theory of mind). Following Winner et al. (1998), participants answered different types of questions about the events which unfolded in stories which ended in either an ironic statement or a lie. Results showed that PD patients were significantly less accurate than HC participants in assigning second-order beliefs during the story comprehension task, suggesting that the ability to make a second-order mental state attribution declines in PD. The PD patients were also less able to distinguish whether the final statement of a story should be interpreted as a joke or a lie, suggesting a failure in pragmatic interpretation abilities. The implications of frontal lobe dysfunction in PD as a source of difficulties with working memory, mental state attributions, and pragmatic language deficits are discussed in the context of these findings.

1. Introduction

Parkinson's disease (PD) is a chronic, neurodegenerative disorder associated with progressive depletion of dopaminergic neurons in the basal ganglia, a set of subcortical structures with extensive connectivity in the brain, particularly to areas of the forebrain (Brown and Marsden, 1998). While idiopathic PD is most commonly recognized by its motor signs, there is now little doubt that many non-motor signs emerge during the progression of the disease (e.g., changes in sensory processing and cognition), although these symptoms tend to vary in nature and severity from one patient to another (Demakis, 2007; Dubois and Pillon, 1997).

In particular, many PD patients exhibit cognitive impairments which affect organization and planning ('executive functions') and/or working memory (Brown and Marsden, 1991; Gabrieli et al., 1996; Lewis et al., 2003; Taylor et al., 1986). In the majority of PD patients, reductions in executive processing and control occur in the absence of broad intellectual decline or dementia. Similarly, there is evidence that PD patients without dementia experience difficulties which affect the processing of verbal (Angwin et al., 2005; Berg et al., 2003;

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Grossman et al., 2002; Lieberman et al., 1990; McNamara and Durso, 2003; Monetta and Pell, 2007; Natsopoulos et al., 1997) and nonverbal language (Dara et al., 2008; Pell and Leonard, 2003). The negative impact of communication impairments on the social and functional independence of individuals living with PD is beginning to be documented (Pell et al., 2006; Pitcairn et al., 1990).

It is of special interest here that certain language abilities, such as those which rely on pragmatic knowledge and awareness, are believed to be highly dependent on intact cognitive resources during language processing tasks (McDonald and Pearce, 1998; Stemmer et al., 1994). Pragmatics is a general term that refers to the use of language in context, including both physical context and aspects such as speaker intentions, mood, and the emotional state of the speaker; as such, pragmatic processing reflects instances where the capacity to communicate rests not only on an intact language system but also on the knowledge of a specific communicative exchange context and high-level capacities (Martin and McDonald, 2003). Pragmatic language functions include the ability to generate appropriate inferences from linguistic material, to interpret metaphorical and nonliteral language (e.g., indirect speech acts, humor), and to interpret language in the context of paralinguistic, nonverbal, and situational cues which inform intended meanings.

A strong link has been made between the ability to understand ''complex'' and pragmatic forms of language and the individual cognitive resource capacity of patients with PD (Grossman et al., 2003; Monetta and Pell, 2007; Monetta et al., 2008b). In a recent study, Monetta and Pell (2007) investigated how participant groups with and without PD processed metaphorical versus literal meanings of language using a timed property verification task (Gernsbacher et al., 2001). They noted a selective decline in the ability to understand more cognitively demanding metaphorical meanings in individual PD patients with impaired working memory capacity when compared to PD patients with working memory scores in the control group range. The ability to generate inferences during story comprehension was also predicted by the working memory capacity of individual PD patients in another recent study (Monetta et al., 2008b). Other researchers have linked deficits in complex sentence processing in PD to underlying reductions in the rate of information processing or strategic allocation of attention (Grossman et al., 2002; Lee et al., 2003). Collectively, these findings argue for additional studies to look at the impact of PD on pragmatic language processing relative to the cognitive resource capacity of individual PD patients.

1.1. *The comprehension of verbal irony and theory of mind (ToM)*

Recognizing verbal irony necessitates the use of pragmatic knowledge to arrive at the intended (i.e., nonliteral) meaning. Irony is expressed when the intended meaning of language is different from or the direct opposite of its usual (i.e., literal) sense (see Gibbs, 2000, for an account of the different forms and functions of verbal irony). The main difference between an ironic remark and a lie, therefore, is whether the listener is *aware* of the context. For example, in the case of an ironic remark, a person may look out the window and say, ''What beautiful weather we're having today!'' when everybody else can clearly see that it is raining outside. Here, the speaker uses words to express something opposite to their literal meaning resulting in an ironic statement. In the case of a lie, a person may look out the window and say, ''What beautiful weather we're having today!'' but in a situation where nobody else can see out the window (and thus, only the speaker is aware of the contradiction). This example demonstrates that ironic remarks and lies are both intentional false statements but their communication goal is completely different (i.e., to emphasize that the weather is in fact poor versus to deceive others about the status of the weather, respectively). In everyday life, one can predict that an inability to distinguish between these two interpretations of the same utterance would culminate in a failure to understand the true intentions of other speakers and could interrupt social interactions in a pronounced manner.

One factor that appears to be critical for understanding verbal irony is an individual's ability to attribute correct second-order beliefs. The ability to attribute mental states to others, also known as ToM, refers to an individual's ability to form representations of others' mental states and to use these representations to understand, predict and judge their utterances and behaviors (see Brownell and Martino, 1998, for more information). Specifically, second-order ToM involves making an attribution about one person's knowledge about another person's knowledge (i.e., determining what one person thinks about another person's thoughts). The evaluation of ToM generally requires participants to represent the false belief of other persons and to predict the other person's actions (Leslie, 1994). Previous studies of clinical populations who typically display pragmatic language deficits (such as right-hemisphere-damaged individuals and autistic children) have reported an inability to distinguish lies from ironic remarks in these groups (Martin and McDonald, 2004; Winner et al., 1998). Moreover, deficits in comprehending irony often correlate strongly with individual deficits in attributing second-order beliefs (i.e., inferring what one person thinks about another person's thoughts; Martin and McDonald, 2004; Winner et al., 1998). While there are hints that the ability to attribute mental states to others is compromised in PD (Saltzman et al., 2000), similar research has not been conducted on patients with PD. Should these patients have difficulties attributing mental states to others, the potential impact of these problems on irony comprehension or other aspects of pragmatic language interpretation is largely unknown.

In the investigation of right-hemisphere-damaged patients conducted by Winner et al. (1998), a series of stories were created that involved a main character who had either a true or a false belief about another character's knowledge. Half of the stories ended with an ironic statement and half ended with a lie. Participants listened to each story and answered a series of questions which probed their comprehension of first-order ToM, second-order ToM and pragmatic reasoning. In the present study, we employed the same paradigm to test whether non-demented PD patients have similar problems differentiating verbal irony from lies and whether these difficulties are associated with the ability to make correct mental state attributions and/or with specific cognitive features of the individual patients (e.g., working memory capacity, executive functions). In light of our previous studies which show that PD patients have difficulties with tasks that involve pragmatic language processing (Monetta and Pell, 2007; Monetta et al., 2008b), and given the documented relationship between ToM and pragmatic language processing (Martin and McDonald, 2004; Winner et al., 1998), we expected that PD participants as a group would demonstrate poor comprehension of ironic remarks overall. In addition, irony comprehension should be closely related to the ability to correctly attribute mental states to others (particularly those referring to second-order beliefs; Winner et al., 1998) and to the executive resource capacity of individual PD patients (e.g., working memory).

2. Methods

2.1. *Participants*

The participants were 11 native English speakers diagnosed with idiopathic PD (mean age: 67, range: 55–86) and 11 healthy control (HC) participants (mean age: 71, range: 56–83), matched for age, sex and education. All participants displayed normal or corrected-to-normal vision as determined by self-report, and acceptable hearing thresholds at the important frequencies for speech intelligibility established prior to testing (minimum of 30 db HL at 500, 1000 and 2000 Hz as confirmed by pure tone audiometric screening).

Diagnosis of idiopathic PD was confirmed by a neurologist on the basis of accepted motor criteria (Calne et al., 1992). Motor disability of individuals within the PD group was in the mild to moderate severity range according to the Hoehn and Yahr staging criteria (Hoehn and Yahr, 1967). All patients were optimally medicated during testing (i.e., conducted during "on" state) as follows: Levodopa–carbidopa ($n = 7$), Dopamine agonists/Mirapex ($n = 4$), Monoamine oxidase B (MAO-B) inhibitor/Selegiline ($n = 3$), Catechol O-methyltransferase (COMT) inhibitor ($n = 2$), amantadine ($n = 3$) and Permax ($n = 2$). Patients with other serious medical conditions (e.g., stroke) or a history of alcohol abuse were systematically excluded. All individuals in both groups were screened for dementia prior to the experiment using the Mattis Dementia Rating Scale (Mattis, 1988). There were no significant differences between the two groups on this measure [$F(1, 20) = .89$, $p = .36$]. The presence and severity of depression in the PD and HC participants were also estimated using the short form of the Hamilton Depression Inventory (Reynolds and Kobak, 1995). On this measure, the HC and PD groups were found to differ significantly [$F(1, 19) = 6.57$, $p < .05$], although this difference was due in large part to the elevated depression scores of two PD patients who were the only two participants to fit the criteria for (mild) depression.

2.2. *Neuropsychological testing*

Each PD and HC participant completed a battery of standardized neuropsychological tests which included measures estimating frontal lobe and executive resource functions (e.g., the ability to switch from one strategy to another, to mentally plan and solve problems, or to inhibit irrelevant information). The tests administered were: 1) Auditory Working Memory test (Tompkins et al., 1994), which is an adaptation of Daneman and Carpenter (1980) for use with neurogenic populations, 2) Color Trail-Making test (D'Elia et al., 1996), 3) Tower of London (Culbertson and Zillmer, 2001), 4) Warrington Recognition Memory test for faces and words (Warrington, 1984), 5) Benton Phoneme Discrimination and Face Recognition subtests (Benton et al., 1983), 6) Forward Digit Span test, and 7) Verbal Fluency test (simple and alternating). The attention subtest from the Mattis Dementia Rating Scale was also examined separately to provide further insight into basic attentional functioning. Statistical analyses (reported in Table 2) indicated that the PD and HC groups performed in a comparable manner on all cognitive and "frontal lobe" measures with the exception of verbal working memory, verbal fluency (alternating), Benton Face Recognition and Color Trail-Making. Tables 1 and 2 summarize the major demographic, clinical, and neuropsychological features of the two groups.

2.3. *Materials*

The pragmatic interpretation short stories created by Winner et al. (1998) were employed. Each story (approximately 250 words in length) described a situation where one person (the witness) observes another person (the protagonist of the story) doing something sneaky (e.g., eating a muffin while the person is on a strict diet). Half of the items were lie stories and half were irony stories; the main difference between the two story types was that for lie stories, the protagonist did not realize that s/he had been caught and uttered a lie to the witness to avoid getting caught. In the irony stories, the protagonist did realize that s/he had been caught and uttered an ironic comment/joke to hide the embarrassment of being caught. Thus, the only structural difference between the stories in each condition was whether the protagonist knew or did not know that the other person knew the truth. There were six irony and six lie stories in total. An example of each story type is provided in Table 3, in addition to the questions

Table 1 – Demographic and clinical characteristics of the HCs and PD patients.

	Group[a]				ANOVA, HC ≠ PD
	HC ($n = 11$)		PD ($n = 11$)		
	M	SD	M	SD	
Age (years)	71.2	7.8	67.1	10.9	NS
Education (years)	15.7	2.7	16.6	2.9	NS
Disease duration (years)	–	–	9.1	3.2	–
Hoehn and Yahr stage	–	–	2.5	.9	–
Hamilton Depression Inventory (/33)[b]	1.3	1.7	4.4	3.6	$p < .05$
Dementia Rating Scale (/144)	140.3	2.9	139.2	2.5	NS

a Each group was composed of 6 female and 5 male participants.
b Increased scores indicate greater impairment.

Table 2 – Neuropsychological test scores for the HCs and PD patients.

	Group				ANOVA, HC ≠ PD
	HC ($n = 11$)		PD ($n = 11$)		
	M	SD	M	SD	
Dementia Rating Scale – attention subtest (/37)	36.6	.7	36.2	1.0	NS
Auditory Working Memory – recall (/42)	38.0	3.8	28.2	5.6	$p < .001$
Verbal Fluency – simple (animals)	17.7	5.3	15.7	3.8	NS
Verbal Fluency – alternating (vegetables/male names)	8.5	2.0	6.5	1.9	$p < .05$
Benton Face Recognition (/54)	47.6	4.8	40.5	5.8	$p < .01$
Benton Phoneme Discrimination (/30)	27.6	1.5	27.2	1.9	NS
Digit Span (span attained)	7.7	1.3	7.0	.8	NS
Warrington Memory – faces	40.8	6.0	39.4	4.6	NS
Warrington Memory – words	48.4	2.6	45.5	4.7	NS
Color Trail-Making test	86.6	21.1	109.2	26.0	$p < .05$
Tower of London (initiation time, sec)	127.8	19.7	111.3	19.8	NS
Tower of London (total correct)	110.0	22.2	107.8	20.2	NS
Tower of London (total moves)	105.6	17.3	96.4	19.9	NS

which were posed to each participant at different intervals in the story (as described below).

2.4. Procedure

Participants were tested during two 25 min sessions separated by a period of one week. In each session participants were instructed to listen to six of the stories (3 lie and 3 irony stories) presented in a fixed random order to all participants. As they listened to the story, participants were simultaneously shown a written version of the story and were asked to read along silently while listening to the tape. They were told that the tape would stop periodically so that the examiner could ask questions and that the participant could reread the text before answering the question (without time limitations). As prosody is often instrumental for conveying irony (Cheang and Pell, 2008), the final statement of each story was read in a neutral tone on the tape to avoid providing prosodic information that could help identify whether the story ended in an ironic joke or a lie. The participants' answers were recorded by the examiner on a scoresheet before continuing with the story; these responses were later graded for accuracy. Six questions were asked at different time points during each story as described below (Table 3 shows the precise location of each question for a sample story).

a) *Fact question*: This question was asked after the opening of the story to verify whether participants could retain enough information to make a basic true/false judgment about pertinent factual information.

b) *First-order belief question*: The first-order belief question required participants to describe a person's belief about the world; this question was asked right after the second character discovered the truth. This question was asked to ensure that the participant realized that the second character knew the truth. Winner et al.'s (1998) stories were constructed in such a way that the first-order belief question was always a true first-order belief question, since in both lie and irony stories, the speaker knew the truth.

c) *Second-order true or false belief question*: This question required the participant to indicate what the protagonist believed about the second character's knowledge. This question was asked right after the protagonist did or did not realize that the second character knew the truth. The correct answer for the second-order belief question was "Yes" for the irony stories and "No" for the lie stories. However, Winner et al. (1998) also included a second part to this question to address the possibility that a person with an intact understanding of second-order beliefs might predict that the speaker in the lie story would lie to cover up when asked the question. In order to capture such a response, and to be sure that this way of reasoning was not penalized, a second-order belief follow-up question was also included.

d) *Second-order belief follow-up question*: This question was asked right after the second-order belief question. In those cases in which the participant responded incorrectly to the second-order belief question but responded to the follow-up question by saying that the speaker did not think what s/he said was true, credit was given to the understanding of second-order beliefs.

e) *Second-order expectation question*: This question was asked after the final utterance. This question assessed the participant's reasoning about the speaker's second-order mental state after they had heard the final utterance.

f) *Interpretation question*: This last question was asked to determine whether or not the participant could discriminate between an ironic joke and a false utterance (lie) after each story had been completed.

3. Results

Initially, a $2 \times 2 \times 5$ mixed ANOVA with the between-subject factor of Group (HC, PD) and within-subject factors of Story Type (Irony, Lie) and Question Type (Fact, First-order belief, Second-order belief, Expectation, Interpretation) was conducted. This analysis revealed a significant main effect of Group [$F(1, 20) = 7.09$, $p < .05$], reflecting that the HC participants were more accurate overall than the PD patients. There was also a significant main effect of Question Type [$F(4, 80) = 19.04$, $p < .0001$], indicating that performance on some questions was better than on others. Significant two-way interactions of Group × Question Type [$F(4, 80) = 2.50$, $p < .05$] and Story Type × Question Type [$F(4, 80) = 6.99$, $p < .0001$] were also revealed. Finally, the three-way interaction of Group × Story Type × Question Type [$F(4, 80) = 3.78$, $p < .01$] was also significant. No other main effects or interactions were found to be significant.

Table 3 – Example of one irony and one lie story (from Winner et al., 1998).

a) Irony story

Tom and Ginger had been married for ten years. One day, a man Ginger worked with asked her to go out to dinner after work. Ginger really liked this man and thought he was quite attractive.

She called home and told her husband Tom she would not be home for dinner because she had a lot of work to do. She said she had to stay late at the office at night. But instead, she went out to a restaurant on a date.

Fact question: Did Ginger work late at the office last night? Yes/No

Tom did not feel like making dinner, so he decided to go to a restaurant. By chance, he picked the same restaurant that Ginger was at with her date. As soon as he got there, he saw Ginger having a romantic dinner with another man. Tom was shocked.

First-order belief question: Did Tom realize that Ginger was on a date and not really at the office? Yes/No

Ginger look up from her plate and saw Tom staring at her. Tom and Ginger exchanged glances. Tom left the restaurant immediately. Ginger's date did not see Tom enter or leave the restaurant. During dinner, Ginger's date asked her, does Tom know that you are having dinner with me tonight?

Second-order belief question: What do you think Ginger told him?

a. Yes, Tom knows that I am having dinner with you tonight.
b. No, Tom does not know that I am having dinner with you tonight.

Follow-up question: Did Ginger think that what she told her date was really true? Yes/No

When Ginger got home, Tom asked her, ''Did you get a lot of work done?'' Ginger replied, ''Yes, I got a lot done since I didn't have any distractions.''

Second-order expectation question: When Ginger said that to her husband, did she think that her husband was going to believe her? Yes/No

Interpretation question: When Ginger said, ''Yes, I got a lot done since I didn't have any distractions'', was she:

a. Lying to avoid getting caught.
b. Joking to cover up her embarrassment.

b) Lie story

Laura and Ed worked in the same department store. One day after work, Ed asked Laura out on a date for that night. Laura did not want to go out with Ed. Laura told him she could not go. She said she had to go visit her mother.

But instead, Laura went to see a movie that night with another friend from work.

Fact question: Did Laura visit her mother that Friday night? Yes/No

Just by coincidence, Ed was sitting a few rows behind Laura at the movie. Ed recognized Laura.

First-order belief question: Did Ed know that Laura was at the movie and not at her mother's? Yes/No

Laura did not see Ed. Ed left the theater before Laura noticed him. Laura's friend asked her during the movie, ''Does that guy Ed who asked you out know that you are at the movies tonight?''

Second-order belief question: What do you think Laura told her friend?

a. Yes, Ed knows that I am at the movies.
b. No, Ed does not know that I am at the movies.

Follow-up question: Did Laura think that what she told her friend was really true? Yes/No

The next day at work, Ed saw Laura and asked her, ''Did you have a nice visit with your mother?'' Laura replied, ''I had a fabulous time.''

Table 3 (*continued*)

Expectation question: When Laura said that to Ed, did she think that Ed would believe her? Yes/No

Interpretation question: When Laura said, ''I had a fabulous time'', was she:

a. Lying to avoid getting caught.
b. Joking to cover up her embarrassment.

To explore the three-way interaction, the mean accuracy data were analyzed separately for each question type using a series of 2×2 mixed ANOVAs with the between-subject factor of Group (HC, PD) and within-subject factor of Story Type (Irony, Lie). Significant interactions were elaborated upon using the Tukey Honestly significant difference (HSD) procedure for multiple comparisons ($p < .05$). These data are illustrated for all question types in Fig. 1. The discussion below focuses on any between-group differences that emerged for each of the five question types.

3.1. *Performance on questions related to ToM and pragmatic interpretation*

a) *Fact question*: Errors in answering the fact question would indicate basic difficulties in following the story. Individuals in both the HC and PD groups had a high degree of accuracy in answering the fact questions for all stories (99% and 100% correct, respectively), indicating that all participants displayed high levels of attention and comprehension while listening to the stories. No significant effects emerged in the analysis of this question.

b) *First-order belief questions*: Errors in answering the first-order belief question would indicate difficulties in drawing inferences. HC participants answered 99% of the first-order belief questions correctly, whereas PD participants answered 92% of the first-order belief questions correctly. The ANOVA revealed a main effect of Group [$F(1, 20) = 6.23$; $p < .05$], which was explained by the fact that PD participants were significantly less accurate than the HC participants on these questions. No main effect of Story Type or interaction of Group by Story Type emerged for this analysis. Brief examination of the individual data indicated that only about half of the PD participants (6/11) committed errors on this task (one PD participant made 3 errors, another made 2 errors, and four made 1 error each). These errors appeared to be relatively evenly distributed across the different stories.

c–d) *Second-order true or false belief questions and follow-up questions*: Following Winner et al. (1998), participants were considered to have an intact understanding of a second-order belief if they answered according to either of the following patterns: 1) they responded correctly to the second-order belief question and then replied to the follow-up question by saying that the speaker thought what s/he said was the truth or 2) they responded incorrectly to the second-order belief question, but then replied to the follow-up question by saying that the speaker did not think what s/he said was the truth. When graded in this manner, results indicated that the HC participants answered the second-order belief question correctly 92% of the time, whereas the PD participants were accurate 74% of the time. The ANOVA performed on these data yielded

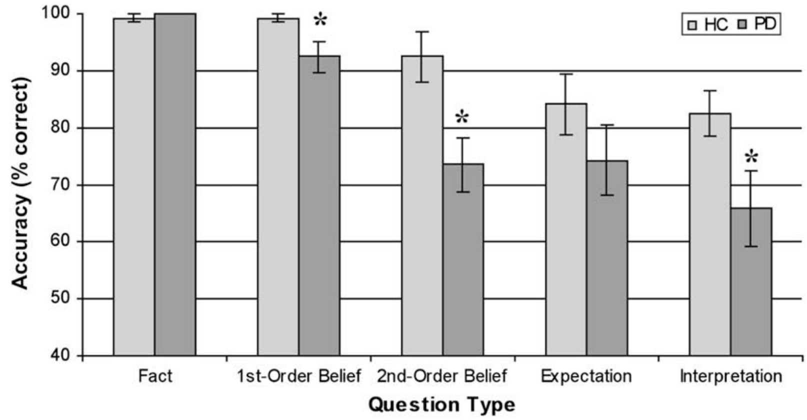

Fig. 1 – Mean accuracy (percent correct responses) of PD participants and HC participants on the story interpretation task by question type.

a significant main effect of Group [$F(1, 20) = 8.54$, $p < .01$], which confirmed that the PD patients were significantly less accurate overall in answering questions based on second-order beliefs. No main effect or interaction with Story Type was observed. In terms of the pattern of responses, PD patients responded correctly to the second-order belief question and answered "yes" to the follow-up question 67% of the time, whereas HC participants responded with this pattern 72% of the time. Brief examination of the individual data indicated that only about half of the PD participants (6/11) committed errors on the ironic stories and 5 PD participants committed errors on the lie stories. Only 2 HC participants committed errors on the ironic stories and 3 HC participants on the lie stories.

e) *Second-order expectation questions*: Recall that this question assessed a participant's reasoning about the speaker's second-order mental state after they had heard the final utterance of the story. As shown in Fig. 1, the HC participants were correct 84% of the time and PD participants were correct 74% of the time in answering these questions. The ANOVA yielded no significant main or interaction effects for this question (all p's $> .05$). Brief examination of the individual data indicated that almost all PD participants (10/11) and half of the HC participants (6/11) committed at least one error in one of the stories. These errors appeared to be relatively evenly distributed across the different stories.

f) *Interpretation questions*: When asked to interpret whether the speaker was telling a lie or making an ironic comment (joke) at the end of the story, the PD group performed less accurately than the HC group (66% *vs* 83% correct, respectively), as shown in Fig. 1. The ANOVA yielded a significant main effect of Group [$F(1, 20) = 4.69$; $p < .05$], confirming that the PD patients were less accurate when responding to the interpretation question. A main effect of Story Type was also found [$F(1, 20) = 18.05$, $p < .0001$] as was a significant interaction of Group × Story Type [$F(1, 20) = 9.80$, $p < .01$]. Post-hoc Tukey (HSD) comparisons on the interaction indicated that whereas the HC participants were comparable in how well they could interpret lies versus jokes, PD patients were significantly less able to recognize the intent of the irony stories, as illustrated in Fig. 2. The individual data indicated that all PD participants committed errors on the interpretation of the ironic joke stories, and only 4/11 PD patients committed errors on the interpretation of the lie stories.

3.2. *Relationship between interpretation questions, ToM, and cognitive measures*

One of the main assumptions of the present investigation was that in order to determine whether an utterance is a lie or ironic remark, it is necessary to keep in mind what a particular

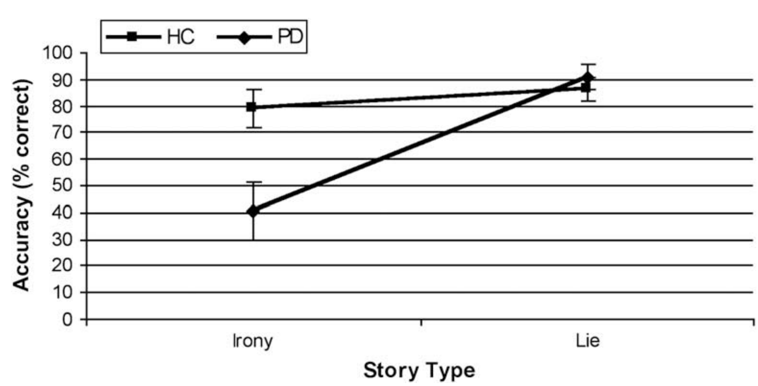

Fig. 2 – Mean accuracy (percent correct responses) of PD participants and HC participants for the pragmatic interpretation question.

speaker thinks that the listener knows (i.e., the speaker's second-order belief). To assess whether a relationship existed between these two abilities, we first ran a correlation analysis including all participants. Results of this analysis showed that these abilities were indeed related, as indicated by a significant correlation between the interpretation and second-order belief questions ($r = .50$, $p < .05$). This finding suggests that all participants used their understanding of the speaker's second-order belief to build an appropriate pragmatic interpretation of the story.

To examine the possible relationship between results of the pragmatic interpretation task and key neuropsychological, demographic and clinical variables, additional correlation analyses were conducted on the data for both the PD and HC groups separately. For each group, significant relationships found between demographic variables (age, education), clinical variables (disease duration and disease severity) and performance on questions relating to the ability to attribute mental states to others (first- and second-order belief questions), to reason about the speaker's second-order mental state (expectation questions) and to make a pragmatic interpretation will first be presented. Next, significant relationships between irony comprehension, ToM and neuropsychological characteristics (i.e., verbal fluency simple, verbal fluency alternating, Tower of London, Color Trail-Making, Auditory Working Memory, Warrington word recognition, Warrington face recognition, Benton Phoneme Discrimination, Benton Face Recognition, and digit span) will be discussed. All correlations reported were significant at $p < .05$ unless otherwise noted.

With respect to the relationship among demographic, clinical and story comprehension question scores of the PD patients, significant correlations were found between the patients' education level and performance on second-order ToM questions ($r = -.63$) and expectation questions ($r = -.77$). However, a closer inspection of the data revealed that two PD participants with the highest education made the most errors on second-order belief and expectation questions which could explain this result. When the analysis was rerun without these two participants, the correlations were no longer significant. With respect to the neuropsychological variables, a marginally significant correlation was observed between second-order ToM ability (assessed by answers to second-order belief questions) and the working memory (WM) capacity of the PD patients ($r = .50$, $p = .057$). In addition, significant correlations were observed between the PD patients' simple verbal fluency scores and performance on expectation questions ($r = .71$) and interpretation questions ($r = .54$), and alternating verbal fluency scores and performance on expectation questions ($r = .54$). Other significant correlations were found between: Color Trail-Making test scores and performance on second-order belief questions ($r = -.60$), expectation questions ($r = -.61$), and interpretation questions ($r = -.76$); Warrington word recognition scores and performance on expectation questions ($r = .69$); Benton Face Recognition test scores and performance on first-order belief questions ($r = .55$); and Benton phoneme recognition scores and performance on first-order belief questions ($r = .60$).

For the HC participants, the only significant correlation found between demographic characteristics and performance on the story comprehension task questions was between age and accuracy on interpretation questions ($r = -.65$). In addition, a number of significant correlations were found between the HC participants' neuropsychological test scores and performance on the story comprehension questions. Specifically, simple verbal fluency scores were significantly correlated with performance on second-order belief questions ($r = .71$). Tower of London total correct scores were significantly correlated with accuracy on second-order belief questions ($r = .55$), expectation questions ($r = .86$), and interpretation questions ($r = .62$). Tower of London total move scores were significantly correlated with accuracy on second-order belief questions ($r = .66$) and expectation questions ($r = .81$). Color Trail-Making test scores were correlated with performance on first-order belief questions ($r = -.56$). Digit span was significantly correlated with performance on interpretation questions ($r = .53$). Finally, scores on the Benton Phoneme recognition test were correlated with accuracy on first-order belief questions ($r = .58$).

4. Discussion

The goal of this study was to further investigate whether pragmatic language deficits are associated with idiopathic PD, in the specific context of interpreting verbal irony from narrative discourse. Our methods also allowed us to evaluate whether pragmatic interpretations of this nature are related to the ability to attribute mental states to others (ToM) and/or to specific cognitive attributes of our PD patients (e.g., working memory, executive functions). As expected, the PD participants tested here were impaired in interpreting the pragmatic intent of remarks at the end of a story, and they were less accurate in answering questions related to the second-order beliefs of story characters. In general, we found that the ability to make pragmatic interpretations was correlated with the ability to attribute second-order beliefs (ToM), and for our PD group, certain estimates of frontal lobe functioning were associated with the ability to make pragmatic interpretations as well as ToM. These preliminary findings are discussed in more detail below to shed light on the nature of pragmatic language deficits in patients with PD and the probable role of fronto-striatal brain circuitry in "high level" language processing.

4.1. *Pragmatic language processing in PD*

An increasing number of studies are exploring whether PD patients experience problems when interpreting the intended or "pragmatically appropriate" meanings of language as defined by its social context. Common situations which require sensitivity to pragmatic features of language include the processing of metaphorical expressions, paralinguistic behaviors, and nonliteral meanings of discourse. Based on previous research, it can be argued that many PD patients exhibit difficulties when language comprehension centers on the processing of nonliteral or pragmatically appropriate meanings of language (Berg et al., 2003; McNamara and Durso, 2003; Monetta and Pell, 2007; Monetta et al., 2008a), including the ability to draw appropriate inferences from discourse

(Monetta et al., 2008b). As an extension of this research, this study found that PD participants often fail to interpret the *intended*, pragmatic meaning of ironic remarks as defined by narrative discourse, although these patients tend to perform at or near ceiling when queried on basic factual content of the same stories (see also Monetta et al., 2008b). Our new data thus serve to bolster claims that relatively ''high level'' aspects of language processing are vulnerable to the effects of PD, even in early to moderate stages of the disease (Berg et al., 2003; Grossman et al., 2002).

For the PD group, we additionally found that two of our measures of frontal lobe functioning, namely verbal working memory span and verbal fluency (simple and alternating), were correlated with key measures on the story interpretation task (i.e., second-order belief questions, and expectation and pragmatic interpretation questions, respectively). Although the correlation between working memory span and second-order belief questions only approached significance, most likely because of the relatively small number of PD patients included in the analysis, this finding is still of interest. Importantly, it is in agreement with our previous studies which have argued for the presence of an important interaction between working memory capacity, or possibly other estimates of cognitive resource capacity (Lee et al., 2003), and the ability to divert sufficient resources to engage in ''complex'' forms of sentence processing which often rely upon pragmatic knowledge and awareness (Monetta and Pell, 2007; Monetta et al., 2008b). The observation that our PD participants displayed poor cognitive flexibility, as reflected by their low verbal fluency task scores (see Troyer et al., 1998), is in agreement with many previous studies which have also reported reductions in verbal fluency in PD patients (see Henry and Crawford, 2004, for a recent meta-analysis on verbal fluency skills in PD). Given that reduced cognitive flexibility has been associated with rigidity for interpreting language (Walsh, 1985), the relationship we observed within our PD group between their verbal fluency skills and pragmatic interpretation abilities may reflect underlying limitations in cognitive flexibility associated with progressive frontal lobe compromise in PD.

The fact that working memory capacity was significantly reduced in our PD group supports the argument that frontal lobe dysfunction contributed to our patients' difficulties in irony comprehension. Working memory functions have been linked to dorsolateral and ventral prefrontal sites (D'Esposito et al., 1995; Owen, 2000). This network includes modulating projections to the caudate nucleus via the fronto-striatal pathways (Collins et al., 2000). Previously we have reported a significant link between working memory deficits in individual PD patients and performance on pragmatic comprehension tasks in which the patients were required to interpret metaphorical language and to draw predictive inferences (Monetta and Pell, 2007; Monetta et al., 2008b). In the present study, we found a relationship between WM capacity and the ability to attribute (second-order) mental states to others, but not with specific measures related to the ability to interpret irony (i.e., the pragmatic interpretation question). However, since there was a significant relationship between the ability to make pragmatic interpretations and to attribute second-order beliefs, one can tentatively argue that these overlapping abilities are both highly dependent on the resource (working memory) capacity of individual PD patients until further studies are conducted in this area. It has been shown that high-level reasoning depends on the ability to manipulate information in working memory (Mutter et al., 2006). Along similar lines, one can speculate that the ability to make complex (second-order) mental state attributions in the service of pragmatic interpretations of language depends crucially on the ability to manipulate information in working memory, which could partially explain why the PD patients evaluated here were impaired in the comprehension of irony. Previous studies have already found a relationship between ToM and working memory in other populations such as individuals with traumatic brain injury (Bibby and McDonald, 2005).

One of the unique contributions of the present study is to show that second-order ToM deficits can also be present in many individuals with PD. While our findings suggest that PD patients were less accurate than control participants in the ability to attribute both first- and second-order beliefs during the irony task, only second-order mental attributions are thought to be critical for understanding the intended meaning of speech acts when a counterfactual or ironic statement is made (Happe, 1993; Martin and McDonald, 2004; Winner et al., 1998). This suggests that irony comprehension and ToM capacity are coupled which is consistent with our data on PD. To our knowledge, only one previous study has reported ToM impairments in the PD population and these researchers linked the deficit to an impairment of the fronto-striatal pathways in PD (Saltzman et al., 2000). Our data appear to fit with these earlier findings by suggesting that second-order ToM attributions and executive resource functions such as working memory in PD contribute in an overlapping manner to pragmatic abilities such as irony comprehension. This could be due to the common reliance of these functions on the fronto-striatal circuitry which is progressively compromised in the course of the disease.

4.2. *Pragmatics, ToM and frontal lobe dysfunction in PD*

One of the well-known roles of the frontal lobes is to co-ordinate behavior and to allow people to use their cognitive abilities in a flexible and adaptive manner. If we consider that the ''rules'' of conversation change according to the context, it is obvious that intact frontal lobe abilities are typically necessary in normal communication for individuals to engage in effective (i.e., contextually appropriate) discourse. Several researchers have previously described the interplay between executive functions, communication, and social behavior (Barkley, 2001; Champagne and Joanette, 2004) and some of these studies have also taken into account different psycholinguistic models that describe how nonliteral language is processed for meaning. While traditional models suggest that the literal interpretation of nonliteral language is always processed first, more recent models propose that under some circumstances both literal and nonliteral meanings are processed simultaneously (see Champagne and Joanette, 2004, for a review). According to these models, when nonliteral (e.g., ironic) meanings are communicated, inhibition processes are necessary to suppress the literal interpretation in favor of the intended, nonliteral meaning. These processes for inhibiting contextually irrelevant meanings are likely to require greater mental flexibility to activate the nonliteral interpretation in context, which again exemplifies the intimate relationship between frontal lobe functions and many pragmatic aspects of language (see McDonald and Pearce, 1998 for further discussion). While our study was not designed to allow inferences about the role of inhibition or other psycholinguistic mechanisms which contribute to nonliteral language processing, future studies of PD would be instructive if they were to address how changes in cognitive resources and ToM deficits impact nonliteral language processing in finer psycholinguistic terms.

The relationship between prefrontal regions, pragmatic processes, and the ability to attribute mental states is also being elaborated by means of functional neuroimaging. In general, functional magnetic resonance imaging (fMRI) studies have linked the ability to attribute mental states to others with the left medial prefrontal cortex, the right temporal pole, and the medial orbitofrontal cortex (Channon et al., 2007; Gallagher and Frith, 2003). Interestingly, other investigations have shown that these three regions are involved in the processing of irony (Eviatar and Just, 2006; Shamay-Tsoory et al., 2005). Based on their fMRI data, Shamay-Tsoory et al. (2005) proposed that the ability to understand irony is mediated by a neural network operating in three successive stages, where the frontal lobes are involved for the final two stages (i.e., the processing of utterance meaning and its contradiction with the context). Our neuropsychological study also suggests that many PD patients are simultaneously impaired in multiple and related functions, including manipulating information in working memory, attributing mental states to others, and interpreting the intended pragmatic meaning of discourse using this information. It is highly possible that deterioration within the fronto-striatal pathways is conjointly responsible for these deficits.

In sum, it can be said from our preliminary data that reductions in fronto-striatal systems, which are known to support WM, social cognition, and different characteristics of executive resource capacity in the broader literature, contribute in large part to the emergence of pragmatic language deficits in many PD patients. We are currently pursuing this hypothesis by evaluating how PD patients interpret lies and ironic comments in relation to their capacity for ToM judgments in a more ecological and contextually enriched context, using videoclips of people interacting from The Awareness of Social Inference Test (TASIT; McDonald et al., 2003). As well, it must be kept in mind that the progressive course of PD impacts negatively on motor and cognitive functions of the basal ganglia before projections to frontal cortices (and fronto-striatal systems) are severely compromised; thus, researchers should continue to investigate the possibility that functional limitations within the basal ganglia are responsible for some of the communication deficits associated with PD such as difficulties with emotion processing (Dara et al., 2008; Pell and Leonard, 2003) or automatic syntactic integration (Friederici et al., 2003). When viewed broadly, the longitudinal profile of communication deficits associated with PD is evolving and complex, and much more needs to be learned about the impact of the disease on language functions and social cognition.

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