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Theory of mind and executive functions in normal human aging and Parkinson's disease

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Abstract

Although the majority of research in theory of mind (TOM) has focused on young children or individuals with autism, recent investigations have begun to look at TOM throughout the lifespan and in other neurological and psychiatric populations. Some have suggested that TOM may represent a dissociable, modular brain system that is related to, but separable, from other brain functions including executive functions (EF). Recently, studies have shown that TOM performance can be compromised following an acquired brain insult (e.g, damage to the right hemisphere). However, the relationship of such impaired TOM performance to other brain functions in these cases has not been explored. This study investigated the effects of both normal human aging and Parkinson's disease on TOM. The relationship of TOM performance and EF in these groups was also examined. The results suggested that although TOM performance appeared compromised in the group of individuals with Parkinson's disease, the elderly control participants were relatively unimpaired relative to younger individuals. Significant relationships between several measures of TOM and EF were also found. The implications of these findings, and also the finding that failure on one measure of TOM did not necessarily predict failure on all measures of TOM, are discussed. (*JINS*, 2000, *6*, 781–788.)

Keywords: Theory of mind, Parkinson's disease, Executive function, Social cognition

INTRODUCTION

The phrase "theory of mind" was originally coined in reference to primates' ability to understand the mental states of others, and to predict behavior based on those states (Premack & Woodruff, 1978). Over the past 15 years, a large amount of research has been dedicated to understanding the developmental progressions of theory of mind in children, and to the relationship that these may have to our social understanding (e.g., Leslie, 1987; Wimmer & Perner, 1983). Increasingly, attention is being paid to the role of brain processes in theory of mind ability, leading to questions about the neural mechanisms of social understanding, and the possible relationship of brain dysfunction to certain social impairments.

Some have suggested that theory of mind operates within the brain with all the properties of a dissociable modular system (Brothers & Ring, 1992). Evidence in support of this model derives from several areas. First, theory of mind abilities seem to develop in a consistent pattern during early childhood (e.g., Chandler et al., 1989; Leslie, 1987; Wimmer & Perner, 1983). Some have suggested that theory of mind development is also consistent across cultures (Avis & Harris, 1991). Second, studies have shown that children with autism have significant difficulties in the area of theory of mind (Happé, 1994; Ozonoff et al., 1991a; Tager-Flusberg & Sullivan, 1994). These deficits appear dissociable from overall mental deficiency, as children with autism perform significantly worse on these tasks than non-autistic children with equivalent IQs (Benson et al., 1994; Happé, 1994). Children with autism are often (but not necessarily) reported to have other cognitive difficulties, including deficits in executive function (Bennetto et al., 1996; Hughes et al., 1994; McEvoy et al., 1993; Ozonoff & McEvoy, 1994). It has been suggested that theory of mind impairments are dissociable from these deficits, since similar cognitive deficits have been shown in some children with Asperger's syndrome and William's syndrome, although not all of these children show evidence of the same difficulties in theory of mind (Karmiloff-Smith et al., 1995;

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Ozonoff et al., 1991b). Finally, studies have shown theory of mind impairments following an acquired brain insult. Winner et al. (1998) reported impaired theory of mind performance in individuals with acquired right-hemisphere brain damage. Stuss (1996) showed that individuals with acquired focal frontal lesions also have difficulty on theory-of-mind-type tasks. Taken together these findings have led some to suggest that theory of mind may represent a *dedicated* modular brain function.

Efforts to identify the brain systems potentially involved in such a modular system have included discussion of the relationship of executive function and theory-of-mind ability. Although it was initially speculated that impaired theory of mind might be a byproduct of executive dysfunction, the above-mentioned studies dissociating theory of mind from executive function ability in children with Asperger's and Williams' syndrome have shown this to be unlikely. Further support for this dissociation can be drawn from studies showing impaired performance on "false-belief" but not "false-photograph" tasks in children with autism (Leslie & Thaiss, 1992), and normally developing preschoolers (Zaitchik, 1990). Rather, it has been suggested that relationship between theory of mind and executive function may exist in terms of common underlying involvement of the prefrontal cortex (Bishop, 1993; Ozonoff & McEvoy, 1994; Ozonoff et al., 1991a). Executive function impairments are frequently reported in individuals with focal damage to the frontal lobes, and have been documented in animal studies of frontal-lobe functioning (Stuss & Benson, 1984**)**. Evidence for the involvement of the prefrontal cortex in human theory of mind has come from functional neuroimaging studies demonstrating frontal activation during theory-of-mind-task performance (Baron-Cohen et al., 1994; Fletcher et al., 1995; Goel et al., 1995; Stone et al., 1998). As noted by Stone et al. (1998), it is important to consider the frontal cortex as playing a role in a larger distributed circuit, rather than representing a localized region for theory-of-mind functioning in the brain.

While the relationship of executive functions to theory of mind has been well documented in individuals with autism (a developmental disorder), this relationship has not been explicitly investigated in the case of acquired theory-of-mind impairment. The purpose of the present study was to examine the possibility of an acquired theory of mind deficit in a group of older adults with presumed impairments in executive function, and to look at the possible relationship of theory of mind to executive functioning. Individuals with Parkinson's disease were selected as an interesting population for study based on an extensive literature that reports that these individuals have impairments in executive function (Bondi et al., 1993; Levin et al., 1988; Litvan et al., 1991; Taylor et al., 1986). If it is the case that individuals with Parkinson's disease do exhibit impairments in theory of mind, such a finding would provide further evidence that theory-of-mind deficits are not necessarily a product of developmental disorder (such as autism), but can exist in conjunction with other neurological disorders later in life. It would also demonstrate a relationship between executive functioning and theory of mind in the case of acquired brain disease.

METHODS

Research Participants

Our study sample consisted of 11 nondemented patients with idiopathic Parkinson's disease referred by a neurologist or from the Parkinson's Association of Victoria. At the time of this study, the participants had received a mean stage rating of 2.5 (range 2.0–3.0) on the modified Hoehn and Yahr (1967) scale. A sample of 8 elderly control participants, consisting of patients' spouses, and 9 university-aged control participants were also included. Written informed consent was obtained from all participants. Persons with chronic medical problems (e.g., hypothyroidism, hypertension) were included as long as it was clear that their medical condition was well controlled, and not believed to be adversely affecting their level of cognition. All patients were being treated with Sinemet at the time of the study. Normal control participants were without complaints of cognitive difficulty during interview, and were not taking any dopaminergic agents.

The Mini Mental Status Exam (Folstein et al., 1975) and the Geriatric Depression Inventory (MMSE; Yesevage & Brink, 1983) were administered to all elderly participants. University-age participants completed the MMSE and the Beck Depression Inventory (Beck & Beck, 1972). All participants scored well above the recommended cut-off for dementia (above 26), and therefore, no one was excluded from the study on this basis. One participant with Parkinson's disease achieved a moderately elevated score on the GDS, and was being treated with antidepressant medication. All participants completed the Vocabulary subtest of the Wechsler Adult Intelligence Scale–Revised (WAIS–R; Wechsler, 1981). This information was used to ensure that the three groups fell within the average level of intellectual ability, and that there were no differences between the groups. Age-adjusted scaled scores were recorded. Demographics for these groups are presented in Table 1.

Measures

Executive functions

The California Card Sorting Task (Delis et al., 1992) is a relatively new sorting task designed to "isolate and measure specific components of problem-solving ability." The test consists of two sets of stimulus cards. Each set is made up of six cards with a single word printed on each card. The cards can be sorted in two equal piles according to various rules (e.g., shape, size, color of the card). For each set, the participants completed two sorting conditions. In the *free sorting* condition, participants were instructed to sort the cards into two piles, with three cards in each pile. After each sort, participants were asked to explain how the piles were

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Table 1. Summary data for the groups

Variable	Parkinson's	Elderly control	University control
Age (years)			
M	70.98	71.61	20.87
SD	13.43	9.42	2.53
Range	48.00–84.83	49.50–79.67	18.58–25.91
Sex			
M	6	3	3
F	5	5	6
Education (years)			
M	12.80	12.75	13.11
SD	0.79	2.05	0.86
Range	12–14	10–17	12.5–15.0
Vocabulary (age SS)			
M	12.45	12.13	11.44
SD	2.81	1.89	2.40
Range	8–17	9–15	7–15

different. Participants were instructed to continue sorting the cards as many different ways as they could until the time limit (3 min) had expired. In the *structured sorting* condition, the examiner sorted the cards into two equal piles according to eight different rules. Participants were given 1 min to explain how the two piles differed. Several measures were recorded from these two conditions. For the free sorting condition, participants were evaluated on the total number of correct sorts, and the total points awarded for their verbal responses. In the structured condition, participants were scored on their verbal responses only.

In the verbal fluency task (letters *F*, *A*, *S*; Spreen & Benton, 1977), participants were given 1 min to generate as many words as they could for each of the letters, *F*, *A*, and *S*, excluding proper names (e.g., Frank), names of places (e.g., France). The total number of words recounted for all three letters was recorded.

The five-point fluency task (also called figural fluency; Lee et al., 1997; Regard et al., 1982) required participants to make as many different designs by joining the five dots (as on a die) as quickly as they could in 3 min. The total number of original designs and the number of repetitions were recorded.

Theory-of-mind tasks

Participants heard two short false-belief stories: one first- and one second-order attribution task (Happé, 1994; Tager-Flusberg & Sullivan, 1994), followed by a series of questions. Participants were read the story aloud, but also were presented with a typewritten copy that they were allowed to keep in front of them while listening to the story and answering the questions, in order to minimize memory requirements. Following each story, participants were asked three types of questions. First, the memory question asked the participant to recall some piece of factual information from the story. This question served as a check to determine whether participants were unable to complete the task because of memory difficulties. Participants would have been excluded from participation if they had been unable to answer these questions correctly. Second, the prediction question required the participant to make some kind of prediction regarding the behavior of one of the characters in the story, based on the available information. The answer to this question was not explicitly available within the body of the story but rather required the participant to infer such information based on the mental states and actions of the characters. Third, in the justification question, participants were asked why they made a particular prediction, and to give a short explanation of their reasoning. Participants received a score of zero or 1 (*incorrect* or *correct*) for each question. Responses were scored independently by two raters, with 100% agreement. Statistical analyses were carried out on the prediction scores only.

In the Droodles Task (Chandler & Lalonde, 1996), participants were shown a cartoon-type picture that was taped inside an 8.5 × 11 cm filing folder. For the first folder/picture, participants were shown only the cut-out window portion of a picture, and asked to provide as many possible guesses as to the true picture content. For the remaining four folders/pictures, participants were first shown and asked to describe the whole picture. Then, the picture was covered so that only a small portion was visible through a cut-out window. Participants were asked to predict what another person (Bill, who has not seen the entire picture) would think that picture was. Then, participants were asked to predict what a second person (Roberta) would think the picture was, if she didn't think the same thing as Bill. Participants received a score of zero or 1 (*incorrect* or *correct*) for their predictions of Bill and of Roberta, for a total score of 4 points for Bill's responses (first-order attribution), and 4 points for Roberta's responses (interpretation).

The "spy" model task was adapted from the hide-and-seek task introduced by Chandler et al. (1989) and Hala et al. (1991), to control for memory and verbal components in

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theory-of-mind performance. The "game board" for this task consisted of an 45×60 cm white erasable board as the base, with pieces of miniature wooden furniture placed on top to simulate an office setting. In this task, participants took the role of a "spy/detective" whose goal it was to retrieve a secret document without getting caught. Participants were informed that because of an unfortunate thunderstorm, they were automatically considered "dripping wet," and therefore they would leave a trail of watermarks everywhere they walked (simulated by tracing their pathway around the model with a blue pen). Participants were instructed to figure out the best way to steal the document from the filing cabinet without anyone knowing that they had taken it. Participants were given the option of demonstrating their plan by moving with the pen around the model, or by explaining their plan verbally. Possible solutions to this puzzle included wiping up the tracks with paper from the garbage, or making more than one set of tracks to confuse the police. Any solution that demonstrated an understanding that they must hide their path to the cabinet was accepted. Participants were scored either *pass* (1 point) or *fail* (0 points).

In the Knower/Guesser ("egg cup") task, adapted from Povinelli et al. (1990), participants were shown four egg cups that had been turned upside down. They were told that a paper clip would be hidden underneath one of the cups. While the clip was being hidden, a cardboard screen was placed in front of the cups, such that the participant could see that the clip was *being* hidden, but not *wher*e it was hidden. Participants were told that after the clip was hidden the screen would be removed. At this point, the examiner and her confederate (another graduate student) simultaneously pointed to the location where each *thought* the clip was hiding. The participants were instructed that the examiner and the confederate would point honestly and would not try to deceive them in any way. Participants were informed that, in order to make the task more difficult for the confederate, she would cover her eyes with a blindfold, while the clip was being hidden. The participants were then given eight trials in which they had to figure out the location of the clip. If at any point the participant verbally indicated that they understood that the clip was always in the location where the examiner was pointing, the procedure was terminated and the participant was given credit for the remaining trials. At the end of eight trials, participants were asked how they knew where the clip was hiding, or if they used any strategies for locating it. Participants were scored on the number of correct guesses they made.

A summary score indicative of one's overall performance on the four measures of theory of mind, was assigned to each participant (TOM composite score). Participants received 1 point for each theory of mind task they successfully completed (maximum = 4 points). Success on the tasks was determined as follows:

1. *Stories*: the participant answered both prediction questions correctly.
2. *Model*: the participant was able to provide one or more possible solutions.
3. *Knower/Guesser*: the participant was able to recognize that the examiner was manipulating the hiding location, and that following the lead of the examiner would ensure success.
4. *Droodles*: the participant was able to give the correct first-order and interpretive answers for all items.

Procedure

Both the elderly and Parkinson's participants were contacted by the one of the authors and invited to participate in the study, either in their homes, or at the University of Victoria. Participants were given a brief description of the study over the telephone, and again before signing the consent form. Each person was given an opportunity to ask questions about the study and procedure before signing the form. The protocol was completed in one session, lasting from $1\frac{1}{2}$–2 hr, taking breaks as needed by the participant. University of Victoria students were invited to participate in this study as part of their course work in an introductory psychology class. Testing was carried out at the University of Victoria, and was identical to the protocol used with the other participants.

RESULTS

Because of the large number of dependent measures and the small sample size, two approaches were taken to reduce the likelihood of committing a Type I error. First, planned group comparisons were initially conducted on the TOM composite score. This procedure was chosen as a sort of omnibus test in order to limit the number of analyses being carried out on a small sample. Subsequently, planned group comparisons were computed for each dependent variable individually, for more exploratory purposes. Second, a more conservative alpha level (.01) was selected for all comparisons. The results should be interpreted within the context of this small sample.

The planned comparisons were one-tailed, based on the specific prediction that individuals with Parkinson's disease would be impaired compared to the elderly control participants, and that the elderly controls would be impaired compared to the younger control subjects. Comparisons were also performed on the mean education and WAIS–R Vocabulary scores of the groups (as shown in Table 1). No significant differences were found. These analyses were two-tailed.

Pearson product–moment correlations were used to investigate the relationship of theory of mind performance to executive functions.

Analyses using depression as a covariate produced the same pattern of results as analyses that omitted depression. Therefore, only the latter are reported.

The results of the comparisons between individuals with Parkinson's disease and their elderly counterparts are pre-

Table 2. Comparison of participants with Parkinson's disease and elderly control participants on measures of theory of mind and executive function

Measure	Parkinson's	Elderly control	t	p
TOM Composite Score (max = 4)				
M	2.36	3.63	−3.10	.004
SD	1.21	0.52		
Stories (prediction; max = 2)				
M	1.36	2.00	−2.68	.007
SD	0.81	0.00		
Model (score 0 or 1)				
M	0.55	1.00	−2.96	.004
SD	0.52	0.00		
Guesser/Knower (# correct; max = 8)				
M	4.27	5.50	−1.29	.104
SD	2.61	2.07		
Droodles (interpretive score; max = 4)				
M	3.64	4.00	−1.03	.157
SD	1.21	0.00		
California Card Sort (total correct sorts)				
M	7.73	7.50	0.23	.412
SD	2.80	1.93		
Five-point fluency (total correct)				
M	18.27	24.00	−2.03	.027
SD	6.47	6.82		
Verbal fluency (total)				
M	30.73	40.63	−1.89	.035
SD	10.70	12.86		

sented in Table 2[1]. Overall, participants with Parkinson's disease scored significantly lower on the TOM composite score than their age-matched counterparts, suggesting that they had difficulty on a greater number of these tasks. Specifically, the false-belief stories and "spy" model were areas of relative difficulty for the participants with Parkinson's disease; they were less able to make correct predictions based on inferences about a story character's belief, and they had more difficulty planning a course of action that could deceive another person. In contrast, as compared to their age-matched controls, participants with Parkinson's disease were equally able to recognize that one individual might hold a different interpretation than another (Droodles), and they were able to recognize that seeing can lead to knowing (Knower/Guesser).

As compared to the elderly control group, participants with Parkinson's disease tended to generate fewer words on verbal fluency, and fewer designs on five-point fluency. They performed equally as well as their age-matched controls in the number of categories they were able to generate on the California Card Sorting Test.

In comparison to the university-age control group, the healthy elderly participants obtained significantly lower scores on the TOM composite score[2] [$t(7) = -2.049$, $p < .05$]. However, closer inspection revealed that both university-aged and healthy elderly participants achieved ceiling level scores on all measures of TOM except the Knower/Guesser task, on which the elderly group performed more poorly [$t(9) = -2.330$, $p = .022$]. On the measures of executive function, the healthy elderly participants generated fewer designs on the five-point fluency test [$t(25) = -2.452$, $p < .01$], and fewer categories on the California Card Sorting Test [$t(12) = -4.985$, $p < .01$] than the university-age participants. The healthy elderly group performed as well as the university-age group on the verbal fluency test [$t(25) = 0.196$, $p = .42$].

The relationship between executive function and theory of mind was examined across all groups. The correlations between measures of executive function and theory of mind are presented in Table 3. Moderate effect sizes were found for most significant and marginally significant correlations.

The intercorrelations between measures of theory of mind for the healthy elderly participants and those with Parkin-

[1]Preliminary analyses indicated that the homogeneity of variance assumption did not hold for any of the theory of mind or executive function variables, except verbal fluency and five-point fluency. However, because the results based on separate variance tests and on standard ANOVA procedures did not differ, only the latter are reported.

[2]Preliminary analyses indicated that the homogeneity of variance assumption had been violated for this variable. Because the results on separate variance tests and on standard ANOVA procedures *did* differ in this case, the separate variance tests ($df = 7$) are reported.

Table 3. Correlations between measures of theory of mind and executive functions for all participants

	TOM measure							
	Droodles		Stories		Model		Knower/Guesser	
Cognitive measure	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Verbal Fluency	.3565	.063	.2889	.136	.3711	.052	.5976	.001
Five-Point Fluency	.1259	.523	.3025	.118	.3476	.070	.5204	.005
California Sorting Task–correct sorts	.3417	.075	.3186	.099	.0495	.802	.4515	.016

son's disease are presented in Table 4. The university-age group was omitted from this analysis because every participant in this group achieved a perfect score on the theory-of-mind measures, and thus would add no variability to the analysis.

DISCUSSION

Increasingly, the world of neuropsychology is becoming interested in the brain bases of social understanding. Researchers have turned to theory of mind as one avenue to explore this relationship in individuals with neurological disorders. The results of this study provide some preliminary evidence of the possibility of acquired theory-of-mind deficits (in Parkinson's disease) rather than a merely developmental phenomenon.

Altogether, there is some suggestion that the participants with Parkinson's disease were impaired as a group, relative to the healthy elderly participants on *some* measures of theory of mind (false-belief stories and the Model) and executive function (five-point fluency and verbal fluency were marginally significant). On the remaining tasks in which there were no significant group differences, it is interesting to note that individual performance among participants with Parkinson's disease was variable, despite reports that these types of tasks are typically accomplished by children between the ages of 4 to 8 years. It is also interesting that the participants with Parkinson's disease in this study did not have difficulty on the card-sorting task compared to elderly controls, despite the fact that previous findings of impairments associated with Parkinson's disease on this test have been reported (Beatty & Monson, 1990). This may reflect the fact that the participants in this study were nondemented and quite high-functioning. Alternatively, lower scores on the tasks requiring speeded performance (i.e., verbal fluency and five-point fluency) may be associated with some bradyphrenia in the participants with Parkinson's disease.

Healthy elderly participants performed more poorly on one measure of theory of mind (Knower/Guesser) and on two measures of executive function (five-point fluency and card sorting) as compared to the university-age participants. The poor performance on the Knower/Guesser task by individual elderly controls was qualitatively different than poor performance of individual participants with Parkinson's disease. In both groups, individuals who persisted in choosing incorrect locations were questioned about their rationale for choosing that location. From these responses, it became more evident that elderly control participants who committed errors tended to be overestimating the requirements of the task, and applied complex logical reasoning in place of a simple solution. In contrast, participants with Parkinson's disease who made similar errors, tended to attribute correct guesses to "luck" and concluded that the placement of the clip was completely random. Given that the elderly group of participants received perfect scores on the other three measures of theory of mind, it is certainly premature to conclude that they have a theory of mind impairment. Performance of these elderly participants is consistent with previous findings that healthy older adults were not impaired on false-belief stories relative to a younger comparison group (Happé et al., 1998).

That some relationship of theory of mind and executive function exists appears to be supported to some extent in our samples of elderly participants and those with Parkin-

Table 4. Intercorrelations between measures of theory of mind for all elderly participants (Parkinson's and controls)

	Stories	Model	Knower/Guesser	Droodles
Stories	1.000	−.208	.186	.578
	–	$p = .393$	$p = .447$	$p = .010$
Model	−.208	1.000	.353	.208
	$p = .393$	–	$p = .158$	$p = .393$
Knower/Guesser	.186	.353	1.000	.380
	$p = .447$	$p = .158$	–	$p = .109$
Droodles	.578	.208	.380	1.000
	$p = .010$	$p = .393$	$p = .109$	–

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son's disease. Several significant correlations between measures of theory of mind and those that are presumed to involve some prefrontal brain functioning (executive function tasks) lend some support to the idea that the prefrontal cortex may play an important role in our capabilities for social understanding. Note, however, that the two constructs are not identical: Some elderly who performed poorly on executive function tasks nonetheless passed some of the theory of mind tasks.

Finally, the pattern of results obtained on the four measures of theory of mind in this study raises an interesting question about the homogeneity of these measures. It is worth noting that success on one measure of theory of mind did not necessarily guarantee success across all theory of mind measures. It is possible that a failure to find significant relationships in these variables is related to the small sample size ($n = 19$ after the university students are omitted). Since many of the healthy elderly subjects were at ceiling for all but the Knower/Guesser task it is also possible that these correlations represent an underestimate of the true relationships among theory-of-mind tasks. Nonetheless, the fact that correlations between these measures were, *at best*, moderate also suggests that the four measures of theory of mind *may not* be evaluating the same underlying construct. Perhaps they are measuring different aspects within a larger framework of social understanding. These questions remain for future research.

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