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Everyday Action Impairment in Parkinson's Disease Dementia

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Abstract

This study examined everyday action impairment in participants with Parkinson's disease dementia (PDD) by comparison with participants with Parkinson's disease-no dementia (PD) or Alzheimer's disease (AD) and in reference to a neuropsychological model. Participants with PDD ($n = 20$), PD ($n = 20$), or AD ($n = 20$) were administered performance-based measures of everyday functioning that allowed for the quantification of overall performance and error types. Also, caregiver ratings of functional independence were obtained. On performance-based tests, the PDD group exhibited greater functional impairment than the PD group but comparable overall impairment relative to the AD group. Error patterns did not differ between PDD and PD participants but the PDD group demonstrated a higher proportion of commission errors and lower proportion of omission errors relative to the AD group. Hierarchical regression analyses showed omission errors were significantly predicted by neuropsychological measures of episodic memory, whereas commission errors were predicted by both measures of general dementia severity (MMSE) and executive control. Everyday action impairment in PDD differs quantitatively from PD but qualitatively from AD and may be characterized by a relatively high proportion of commission errors—an error type associated with executive control deficits. (*JINS*, 2012, *18*, 787–798)

Keywords: Naturalistic action, Activities of daily living, Dementia, Functional abilities, Ideational apraxia, Instrumental activities of daily living, Executive functions, Episodic memory

INTRODUCTION

The term everyday action impairment (EAI) denotes difficulties performing everyday tasks involving common objects, multiple steps, and a practical end-goal (e.g., meal preparation; Schwartz & Buxbaum, 1997). EAI is associated with grave consequences across dementia syndromes (Knopman, Berg, & Thomas, 1999; Noale, Maggi, & Minicuci, 2003), including Parkinson's disease dementia (PDD; McKeith et al., 2005). Although neuropsychological research on EAI is accumulating (Marcotte & Grant, 2009), there are still many gaps in the literature. For example, EAI is rarely characterized in light of a neuropsychological model, and most studies offer only cursory descriptions of functional deficits without detailed performance analysis. Very few dementia studies have focused on syndromes besides Alzheimer's disease (AD) and fewer still have compared EAI across syndromes. To address these gaps, this study evaluated EAI in individuals with PDD against individuals with Parkinson's disease-no dementia (PD) or AD using detailed error analysis of performance-based tasks informed by a neuropsychological model (Giovannetti, Bettcher, Brennan, Libon, et al., 2008).

Little is known about EAI associated with PDD/PD. Self- and caregiver-reports reveal that even mild cognitive deficits in PD interfere with complex everyday activities (Cahn et al., 1998; Rosenthal et al., 2010). Shulman et al. (2006) showed that PD participants underestimated their functional difficulties by comparing self-report and performance-based measures of everyday functioning. Detailed performance analysis on a computer-simulated cooking activity with a dual task component demonstrated rigid attention in PD participants, as they performed well on cooking at the expense of the secondary task (Bialystok, Craik, & Stefurak, 2008). In PDD, deficits in sustained and

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focused attention are strongly associated with caregiver report of functioning, even after controlling for motor symptoms (Bronnick et al., 2006). Cumulatively, these studies show an association between *cognitive* deficits and functional difficulties in PD/PDD and highlight the importance of detailed performance-based assessments.

Most investigators agree that *overall level* of EAI is moderately associated with overall level of cognitive impairment (Marcotte & Grant, 2009). Therefore, we expected that PDD participants would show greater overall EAI than PD participants but comparable overall EAI as AD participants of equal dementia severity. By contrast, there is little consensus in the literature concerning the link between *specific* neuropsychological deficits and specific *patterns* of everyday action errors. Our group has developed a neuropsychological model of EAI that emphasizes the role of episodic memory, task knowledge, and executive control processes; the model was based on results from performance-based assessments and traditional neuropsychological measures with between-group comparisons and data reduction analyses (Giovannetti, Bettcher, Brennan, Libon, et al., 2008; Giovannetti, Schmidt, Sestito, Libon, & Gallo, 2006; Giovannetti, Schwartz, & Buxbaum, 2007; Kessler, Giovannetti, & MacMulen, 2007). On this model (hereafter Omission-Commission Model), deficits in episodic memory and/or task knowledge (i.e., script knowledge; Cosentino, Chute, Libon, Moore, & Grossman, 2006; Schank & Abelson, 1977) render individuals incapable of recalling or accessing task goals and lead to the omission of large portions of everyday tasks (i.e., omission errors). More specifically, the type of episodic memory deficit associated with omissions is *at the level of encoding or retention*, characteristic of the anterograde amnesia commonly observed in AD. By contrast, executive control deficits, specifically poor working memory and mental control, lead to inaccurate performance of task steps (i.e., commission errors) because of disorganization and distractibility, but they do not necessarily preclude task accomplishment. Alternate models suggest that EAI is homogeneous across even diverse patients and best explained by overall level of global cognitive impairment (Bouwens et al., 2008; Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Schwartz, Segal, Veramonti, Ferraro, & Buxbaum, 2002; Schwartz, et al., 1998, 1999) or that diverse neuropsychological deficits lead to similar functional deficits because of the complexity of everyday tasks (Buxbaum, Schwartz, & Montgomery, 1998; Hartmann, Goldenberg, Daumuller, & Hermsdorfer, 2005). These alternate accounts predict comparable patterns of EAI across groups of comparable dementia severity.

EAI in PDD was evaluated using the Omission-Commission Model framework. We hypothesized that the neurocognitive deficits that differentiate PDD, PD and AD participants would lead to differential *patterns* of everyday action impairment. We predicted that individuals with PDD, known to exhibit greater executive control deficits than individuals with AD (Calderon et al., 2001; Kraybill et al., 2005; Lambon Ralph et al., 2001; Libon, et al., 2001; Walker, Allen, Shergill, & Katona, 1998), would show a higher rate of commission than omission errors. By contrast, individuals with AD would demonstrate a higher rate of omissions than commissions, considering relatively greater impairment in episodic memory and task knowledge. Because individuals with PD demonstrate relatively circumscribed deficits in executive control, we predicted that they would show a pattern of errors similar to participants with PDD, committing more commissions than omissions. We also used correlation and regression analyses to evaluate relations between specific action errors and specific neuropsychological processes. Based on the Omission-Commission Model, we hypothesized that omissions would be most strongly associated with measures of episodic memory, whereas commissions would be most strongly associated with measures of executive control.

METHODS

A prospective between-group design was used to compare everyday functioning across individuals with PDD, PD, or AD on performance-based assessments and caregiver reports.

Participants

Participants were recruited from university-affiliated specialty clinics in Philadelphia following comprehensive diagnostic evaluations. One participant could not complete the study because of illness requiring hospitalization. The remaining participants included 39 individuals with mild-moderate PD (Hughes, Daniel, Kilford, & Lees, 1992) 19 of whom also met criteria for dementia (PDD; Task Force on DSM-IV, 2000), and 20 individuals with mild-moderate AD (McKhann et al., 1984). One participant met clinical criteria for dementia with Lewy Bodies (DLB; McKeith et al., 2005) and was included in the PDD group; his performance fell within the PDD range on all variables. PDD/PD participants were receiving dopaminergic therapy and were tested in the "on" state; AD participants were taking acetylcholinesterase inhibitors.

As shown in Table 1, the PDD and AD groups were significantly older and demonstrated greater overall cognitive impairment than the PD group on the Mini Mental-Status Exam (MMSE) and Dementia Rating Scale-2 (DRS-2). The PDD and AD groups did not significantly differ in age or dementia severity, but the AD group had significantly lower education than the PDD and PD groups. The mean Unified Parkinson's Disease Rating Scale (UPDRS)-Motor Exam score was higher for the PDD participants (suggesting greater impairment), but the difference was not statistically significant; the UPDRS was not administered to AD participants.

Procedures

The Temple University Institutional Review Board (IRB) and the IRB of each outpatient clinic approved this study. All participants provided informed consent, were tested in their homes using a standardized testing table, and were compensated $70.

Table 1. Means, Standard Deviations, and Statistical Comparisons for Demographic Variables between PDD, PD, and AD Groups

	PDD (n = 20)		PD (n = 20)		AD (n = 20)		ANOVA*		
	M	SD	M	SD	M	SD	F	p	Post-hoc Comparisons
Age (years)	78.15	5.85	68.45	6.32	75.55	4.94	15.33	<.001	PD < (PDD = AD)
Education (years)	15.00	3.43	16.00	3.43	13.15	2.74	5.24	.008	AD < (PD = PDD)
UPDRS Motor Exam (max = 52)	25.50	7.39	20.68	11.61	—	—	2.41	.129	PD = PDD
MMSE (max = 30)	22.70	3.51	28.00	1.56	21.95	3.43	23.49	<.001	PD > (PDD = AD)
DRS-II (max = 144)	114.2	11.97	138.20	5.30	112.2	11.11	41.84	<.001	PD > (PDD = AD)

*df = 2, 57; UPDRS = Unified Parkinson's Disease Rating Scale Total Score; MMSE = Mini Mental-Status Examination Total Score; DRS-II = Dementia Rating Scale, Second Edition Total Score.

Neuropsychological protocol

Tests of executive control, episodic memory, and global cognitive functioning were administered (see Table 2). Test selection was based on the Omission-Commission Model and past findings showing significant relations with performance-based measures of action (Buxbaum, Schwartz, & Carew, 1997; Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Giovannetti, Bettcher, Brennan, Libon, Kessler, et al., 2008; Kessler et al., 2007; Nadler, Richardson, Malloy, Marran, & Hosteller Brinson, 1993; Schwartz, et al., 1998, 1999, 2002) and/or differences between AD and PD/PDD participants (Benedict, Schretlen, Groninger, & Brandt, 1998; Delis, Kaplan, & Kramer, 2001; Mattis, 2001; Warrington, 1984). Neuropsychological variables were combined into composite scores (Episodic Memory, Executive Control) to reduce analyses. Raw test scores were converted to *Z*-scores based on the mean and standard deviation of the entire sample ($n = 60$); the average Episodic Memory and Executive Control *Z*-score was computed to form each composite. Correlation analyses confirmed that the scores comprising each composite were significantly and strongly correlated with each other (Episodic Memory $r > .63$; $p < .001$ for all; Executive Control $r > .36$; $p < .006$ for all).

Caregiver ratings. Caregivers rated participants' functioning in the home using a modified version of the Instrumental Activities of Daily Living and Physical Self-Maintenance scales developed by Lawton and Brody (1969). On this version, caregivers provide ratings for 15 tasks using a three-point scale: (1) independent; (2) requires assistance; (3) entirely dependent. Higher total scores (max = 45) indicate greater dependence. Only caregivers who had at least weekly contact with the participant were included; three participants (1 PD, 2AD) did not have available caregivers.

Performance-based Assessments. Two performance-based measures of everyday action were administered and videotaped for scoring.

Direct Assessment of Functional Status (DAFS; Loewenstein, et al., 1989)

The DAFS is a sensitive performance-based measure of higher order functional abilities among older adults. It has been extensively researched and has excellent psychometric properties (Farias, Harrell, Neumann, & Houtz, 2003; Loewenstein, et al., 1992, 1995). Six of the original 14 DAFS tasks were included in this study, because they were appropriately difficult for our sample and they fit our definition of everyday action (i.e., multiple steps, require object use/selection, etc.): Eating; Telephone Skills; Preparing a Letter for Mailing; Counting Currency; Writing a Check; Balancing a Checkbook. Points (max = 36) were awarded for steps that were completed accurately according to guidelines set forth by Loewenstein et al. (1989); higher scores indicate better performance. Participants were not penalized for clumsiness or poor dexterity. Normative data indicate that healthy older adults are at or near ceiling on these tasks, earning an average of 99% of the 36 points (Loewenstein et al., 1989).

Naturalistic Action Test (NAT; Schwartz, Buxbaum, Ferraro, Veramonti, & Segal, 2003)

The NAT evaluates cognitive difficulties in everyday tasks and has been validated with participants undergoing inpatient rehabilitation for head injury (Schwartz et al., 1998, 2002, 2003) or stroke (Buxbaum et al., 1998; Schwartz et al., 1999) and individuals with dementia (Giovannetti, Bettcher, Brennan, Libon, Burke, et al., 2002; Giovannetti et al., 2006; Giovannetti, Bettcher, Brennan, Libon, Burke, et al., 2008; Giovannetti, Bettcher, Brennan, Libon, Kessler, et al., 2008; Giovannetti, Libon, & Hart, 2002). NAT scores are not influenced by education, gender, or hemiparesis (Buxbaum et al., 1998; Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Schwartz, et al., 1998, 1999, 2002, 2003; Sestito, Schmidt, Gallo, Giovannetti, & Libon, 2005). Among dementia patients, NAT scores significantly correlate with functioning in the home (Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Giovannetti, Bettcher, Brennan, Libon, Kessler, et al., 2008).

The NAT includes three tasks: (1) prepare toast with butter and jelly and coffee with cream and sugar; (2) wrap a gift while distractor objects are included on the tabletop; and (3) pack a lunchbox with a sandwich, snack, and a drink and pack a schoolbag with supplies for school with several crucial objects stored out of view in a drawer containing additional, potentially distracting objects. The global "NAT Score" reflects overall level of performance/impairment and combines

Table 2. Neuropsychological Protocol

Domain	Test	Description, Dependent Variable, Range	Reference
Episodic Memory	Warrington Recognition Memory Test	Includes subtests for words and faces requiring participants to view 50 target words/faces and then immediately recognize them within a set of 50 distractor words/faces; dependent variable = total correct (range 0 to 100)	Warrington, 1984
	Hopkins Verbal Learning Test- Revised	A 12-word list is presented over 3 learning trials, delayed free recall and 24-word yes/no recognition is administered after a 20–25 minute delay; dependent variable = recognition discrimination index (true positives—false positives; range −12 to +12)	Benedict et al., 1998
	DRS-II Memory	Includes a delayed recall of a 5-word sentence, orientation items, immediate recognition of words and designs (range 0–25)	Mattis, 2001; Nadler et al., 1993
Executive Control	WAIS-III Digit Span-backward	Numbers are read aloud by the examiner at a rate of 1 digit per second, the number sequence (ranging from 2 to 8 digits) must be restated in the reverse order (range = 0–14 correct items)	Wechsler, 1997
	DKEFS Trail Making Test- Letter Number Switching*	Requires rapidly drawing a line alternating between letters of the alphabet and numbers in their proper sequential order (range 0–240sec)	Delis, Kaplan, Kramer, 2001
	DRS-II Initiation/ Perseveration	Includes a fluency task, repetition, and execution of complex motor sequences (range 0–37)	Mattis, 2001; Nadler et al., 1993

DRS-II = Dementia Rating Scale, Second Edition; WAIS-III = Wechsler Adult Intelligence Scale, Third Edition; DKEFS = Delis Kaplan Executive Function System.
*We were concerned that scores on this test might be influenced by the motor symptoms associated with PD/PDD. However, the strong correlations with other untimed and non-motor Mental Control measures suggested that this score was not capturing *only* low-level motor dysfunction in this sample.

the proportion of task steps accomplished with the sum of a subset of key errors that have been shown to occur frequently in neurologically impaired patients. Each task is assigned a score ranging from 0 (Accomplishment Score<50% & 0 or more key errors) to 6 (Accomplishment Score = 100% &<2 key errors); task scores are then summed (i.e., NAT Score range = 0–18). NAT Scores below 14 suggest impairment among older adults (Sestito et al., 2005).

Detailed Analyses of Performance-Based Assessments

All DAFS and NAT tasks, except the DAFS Eating tasks, were further coded as described below. Eating items were not further analyzed because all participants performed these items perfectly.

Time to completion

The time taken to complete the DAFS and NAT tasks was recorded in seconds. Timing began at the point at which the examiner completed the instructions and terminated at the point when the participant stated he/she was finished or performed the final task step.

Comprehensive Error Score (CES)

The total number and type of errors made on the DAFS and NAT were recorded based on the error scoring procedures described in Table 3 and detailed in prior publications (Buxbaum, Schwartz, Coslett, & Carew, 1995; Buxbaum et al., 1997; Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Giovannetti, Bettcher, Brennan, Libon, Burke, et al., 2008; Giovannetti, Bettcher, Brennan, Libon, Kessler, et al., 2008; Schwartz et al., 1998, 1999, 2003). Physical assistance was provided without making eye contact or conversation when the intended action was clearly indicated. Assistance was offered only for steps that required motor dexterity or strength (e.g., opening jars, stabilizing the wrapping paper roll while the participant cut the paper). This type of assistance was offered so that the CES would not reflect gross motor difficulties (e.g., tremor, weakness).

Error type distributions

Prior studies have shown that NAT omission and commission error types (see Table 3) reflect dissociable constructs and that diverse patient populations differ on the distribution of errors from each category (Giovannetti, Schwartz, & Buxbaum, 2007; Giovannetti, Bettcher, Brennan, Libon, Kessler, et al., 2008; Kessler et al., 2007). In some studies, action addition errors have been associated with both commission and omission errors (Giovannetti, Bettcher, Brennan, Libon, Kessler, et al., 2008); in other studies action additions have been conceptualized as a type of commission error (Buxbaum et al., 1998; Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Schwartz et al., 1998, 1999).

To assess the pattern/distribution of errors, the proportion of errors from each error category was calculated from the total number of errors: Proportion Omission = Total Omissions/ Total CES; Proportion Commission = Total Commissions/ Total CES; Proportion Addition = Total Additions/Total CES. Proportion scores were calculated using CES from both the NAT and DAFS to include errors from a wide range of tasks and

Table 3. Comprehensive Error Score Error Categories

Error Category	Definition	Examples
Omission	a step is not performed	does not add sugar to coffee; does not add stamp to envelope
Commission		
Substitution	similar, alternate object is used in place of target object	spreads butter on toast with spoon instead of knife
Sequence	anticipation of a step; steps or subtasks performed in reverse order	butter on bread without toasting; applies jelly on bread then applies butter; dials telephone before lifting receiver
Perseveration	a step is performed more than once or for an excessive amount of time	adds butter/jelly repeatedly to toast; adds multiple stamps on letter
Other	correct object is used, but with an inappropriate gesture; the spatial relationship between objects is incorrect; a step is performed, but without the appropriate object	grasps scissors like knife; cuts too small a piece of wrapping paper; rips wrapping paper (i.e. does not use scissors)
Action-Addition	performance of an action not readily interpreted as a task step	puts toast in creamer; writes off-topic note on balance sheet

to reduce the number of statistical comparisons. Total error scores were used in correlation/regression analyses.

Inter-rater reliability

High inter-rater reliability has been reported for detailed analyses of the NAT (Buxbaum et al., 1998; Schwartz et al., 1998, 1999, 2003). However, because these detailed scoring procedures have not been used to evaluate DAFS performance, inter-rater reliability was evaluated for all DAFS detailed scores. Fifteen participants (25% of the sample) were randomly selected and coded separately by two coders (G.S. & F.R.). Discrepancies were noted for reliability analyses but then reconciled for final analyses. Discrepancies were reconciled following videotape review and discussion with a third coder (T.G.).

Statistical Analyses

Analyses of covariance (ANCOVA), controlling for age and education, were used to examine the effect of Group (PDD, PD, AD) on neuropsychological tests, caregiver reports, and performance-based variables. One-way ANCOVAs were used for *post hoc* comparisons between the groups when omnibus ANCOVAs were significant. Age was included as a covariate for *post hoc* comparisons including the PD group and education was included as a covariate in all *post hoc* comparisons including the AD group. Effect sizes for between-group differences were estimated using Cohen's d [.2 = small; .5 = medium; .8 = large (Cohen, 1988)]. Relations between total error scores and neuropsychological variables were assessed using bivariate correlations and hierarchical linear regressions.

RESULTS

Neuropsychological Characterization of the Groups

As shown in Table 4, there was a significant effect of Group for both Composite Scores.[1] *Post hoc* comparisons showed the PDD and AD groups exhibited greater impairment than the PD ($p < .001$; $d > .86$ for all comparisons). The PDD group demonstrated greater executive control deficits than the AD group ($p = .051$; $d = 1.23$), whereas the AD group demonstrated greater episodic memory impairment than the PDD group ($p < .001$; $d = 1.94$).

[1] To reduce the number of analyses, between group comparisons were made for only the Composite Scores.

Caregiver Ratings

As expected, there was a significant effect of Group on the caregiver ratings (Table 5). *Post hoc* analyses showed caregivers of the non-demented PD group reported lower scores (greater independence) as compared to caregivers of the dementia participants ($p < .002$; $d > 1.31$ for all comparisons). Comparisons between the dementia groups showed AD participants were more independent than PDD participants ($p = .022$; $d = .86$).

Performance-Based Assessments: Global Scores

There was a significant effect of Group on the NAT Score and DAFS Global Score (Table 5). *Post hoc* analyses showed no significant difference between the PDD and AD groups (NAT Score $p = .76$; $d = .09$; DAFS $p = .25$; $d = .31$). Both dementia groups (PDD, AD) performed worse than the PD group ($p < .001$; $d > 1.7$ for all comparisons). Note that even PD participants exhibited relatively lower scores as compared to published data from healthy older adults on the DAFS (Lowenstein et al., 1998) and NAT (Giovannetti, Bettcher, Brennan, Libon, Burke, et al., 2008).

Performance-Based Assessments: Detailed Analyses

Inter-rater reliability

Raters showed strong agreement for identifying DAFS actions as correct versus incorrect (90% agreement; Cohen's kappa = .78) and identifying a DAFS error as a commission versus an omission (86% agreement; Cohen's kappa = .76). The raters also were reliable in recording the time for completion for each DAFS task ($r = .99$; $n = 15$; $p < .001$).

Table 4. Means, Standard Deviations, and Between-Group Statistical Comparisons for Neuropsychological Variables

	PDD ($n = 20$)		PD ($n = 20$)		AD ($n = 20$)		ANCOVA* controlling for age and education		
	M	SD	M	SD	M	SD	F	p	Post-hoc Comparisons
Episodic Memory									
Warrington Recognition Memory Test	70.53	13.13	84.4	9.52	59.29	9.14			
Hopkins Verbal Learning Test	6.35	2.85	9.25	1.65	1.82	2.96			
DRS-II Memory	17.00	3.82	23.6	1.85	13.35	3.94			
Episodic Memory Composite Score	−.11	.60	.88	.38	−.94	.48	43.47	<.001	PD > PDD > AD
Executive Control									
Digit Span Backwards	4.80	1.54	7.10	2.67	5.83	2.64			
DKEFS Trail Making Test- Letter Number Switching	234.40	15.85	133.05	58.34	198.17	63.74			
DRS-II Initiation/Perseveration	24.84	5.52	36.60	2.66	27.00	7.39			
Executive Control Composite Score	−.60	.34	.73	.55	−.13	.84	12.18	<.001	PD > AD > PDD

DRS-II = Dementia Rating Scale, Second Edition; DKEFS = Delis Kaplan Executive Function System *df = 4, 55.

Table 5. Means, Standard Deviations, and Between-Group Comparisons for Measures of Everyday Action

	PDD ($n = 20$)		PD ($n = 20$)		AD ($n = 20$)		ANCOVA* controlling for age and education		
	M	SD	M	SD	M	SD	F	p	Post-hoc Comparisons
Caregiver Report									
ADL/IADL Caregiver Report (max = 45)	28.37	6.57	16.33	2.07	22.45	7.26	11.76	<.001	PD < AD < PDD
Overall Scores on Performance-based Measures									
DAFS Total Score (max = 36)	23.60	6.33	31.95	2.54	25.42	5.08	5.34	.008	PD > (AD = PDD)
NAT Score (max = 18)	9.60	4.82	16.50	2.57	9.25	3.24	14.52	<.001	PD > (AD = PDD)
Time to Completion (in seconds)									
NAT Time	1638.89	841.59	940.95	377.88	898.68	499.77	6.02	.004	(PD = AD) < PDD
DAFS Time	905.37	353.79	435.35	290.32	599.37	282.17	5.45	.008	(PD = AD) < PDD
Comprehensive Error Score (CES)									
NAT CES Total	19.10	10.90	5.00	4.93	17.90	6.80	5.80	.005	PD < (AD = PDD)
DAFS CES Total	12.90	5.94	4.80	3.25	11.90	5.37	12.95	<.001	PD < (AD = PDD)

ADL = activities of daily living; IADL = intrumental activites of daily living; DAFS = Direct Assessment of Functional Status; NAT = Naturalistic Action Test; *df = 4, 55 except for ADL/IADL ANCOVA df = 4, 52.

Time to completion

There was a significant effect of Group on Time to Completion (Table 5). The PDD group had significantly longer times than both the PD and AD groups on the NAT ($p < .001$; $d > 1.30$ for both) and the DAFS ($p < .017$; $d > .96$ for both). There was no significant difference between the AD and PD groups (NAT $p = .84$; $d = .09$; DAFS $p = .36$; $d = .57$). The effect size for the PD *vs.* AD comparison of DAFS Time was medium, suggesting that this difference might have reached statistical significance with greater power.

Total comprehensive error score

There was a significant effect of Group on the CES for both the NAT and the DAFS (Table 5). As expected, the dementia groups (PDD, AD) made significantly more errors than the PD group (NAT $p < .001$; $d > 1.78$ for both; DAFS $p < .001$; $d > 1.64$ for both). The PDD and AD groups did not differ ($p > .51$; $d < .17$ for both).

Error patterns

Consistent with prior studies of dementia participants (Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Giovannetti, Bettcher, Brennan, Libon, Kessler, et al., 2008), sequence and substitution errors were the most frequent commissions. Relatively few action addition errors were made (i.e., <10% of all errors). Therefore, we examined relations among action addition errors and the other error categories to determine whether additions could be combined with commissions as in prior studies. In fact, action additions correlated significantly with commissions ($r = .50$; $p < .001$) but not omissions ($r = .21$; $p = .112$). Therefore, we chose to analyze a single commission error category to reduce the number of statistical comparisons while increasing power in the analyses, which was desirable given our sample size.

The distributions of Proportion Omissions and Proportion Commissions across the groups are shown in Figure 1. ANCOVA showed a significant effect of Group on Proportion Omission [$F(4,55) = 12.05$; $p < .001$]. As predicted, *post hoc* comparisons showed that the PDD group did not significantly differ from the PD group ($p = .118$; $d = .68$), although the effect size for this difference was medium. The AD group demonstrated the highest Proportion Omission of the entire sample, as they differed significantly from both the PDD ($p = .028$; $d = .86$) and PD ($p = .017$; $d = 1.74$) groups. Between-group analyses of the Proportion Commission were not performed, because after combining commission and addition errors, this score was the reciprocal of Proportion Omission.[2] Within-participant analyses showed error proportions patterned differently across the groups. As predicted, PDD and PD participants showed a similar error pattern, with a significantly higher Proportion Commission than Proportion Omission (PDD $p < .024$; $d = 1.09$; PD $p < .001$; $d = 2.51$). Participants with AD showed no significant difference between their Proportion Omission and Proportion Commission scores ($p = .313$; $d = .46$).

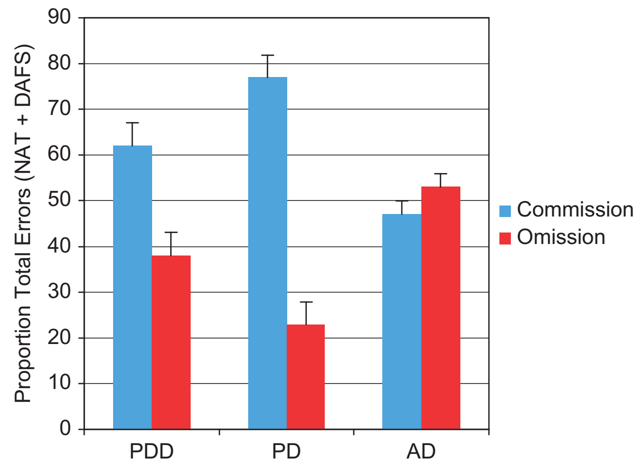

Fig. 1. Mean Proportion Omission and Proportion Commission across the PDD, PD, and AD groups. Error bars reflect + 1 SEM.

Relations Among Neuropsychological Variables and Everyday Action Errors

Total omissions and commissions correlated negatively and significantly with all neuropsychological variables, indicating that greater neuropsychological impairment was associated with more errors (see Table 6).

Hierarchical multiple regression was used to examine whether relations between neuropsychological tests and action errors might be best explained by overall level of cognitive impairment or a combination of neuropsychological measures. Two regression analyses were performed with MMSE[3] (i.e., overall impairment) in the first block and Episodic Memory and Executive Control composite scores in the second block. In the first regression, omissions was the dependent variable; the best model accounted for 57% of the variance [$F(2,52) = 23.34$; $p < .01$] with the Memory Composite emerging as the only significant predictor variable. As shown in Table 7, the change in the amount of variance explained by only the MMSE following inclusion of the Memory Composite Score was statistically significant.

Total commissions was the dependent variable in the second regression (Table 8). The best model accounted for 38% of the variance [$F(2,52) = 10.68$; $p < .01$] with MMSE and the Executive Control Composite emerging as the

[2] When Proportion Commission was analyzed without additions, the results did not change. The omnibus ANCOVA showed a significant effect of Group [F (4, 55) = 4.69, $p = .01$] with post-hoc comparisons showing PDD participants did not significantly differ from PD participants ($p = .24$, $d = .56$) but differed significantly from AD participants ($p = .031$, $d = .82$). AD and PD participants also differed significantly ($p = .027$, $d = 1.46$). There was no effect of Group on Proportion Addition [F (4, 55) = .90, $p = .412$)].

[3] The DRS-2 was not used as a measure of overall functioning, because portions of the DRS-2 thoroughly assess key components of the Omission Commission Model and are included in the Episodic Memory and Executive Control Composite Scores. The MMSE and DRS-2 showed similar results across the study groups (see Table 1) and the two measures were strongly correlated ($r = .78$, $p < .001$).

Table 6. Single Order Correlations (r values) for NAT Error Scores x Neuropsychological Test Variables ($n = 60$)

	Everyday Action Errors	
	Total Omissions	Total Commissions
MMSE	−.71*	−.69*
Episodic Memory Composite	−.86*	−.66*
Executive Control Composite	−.59*	−.58*

*$p < .001$

only significant predictor variables. The change in the amount of variance explained by only the MMSE following inclusion of the composite scores did not reach statistical significance.[4]

DISCUSSION

This novel study characterized EAI in PDD in contrast to PD and AD and in reference to a neuropsychological model. Although PDD participants exhibited a greater degree of EAI than PD participants, both groups exhibited a similar pattern of action errors that was qualitatively different from that of AD participants. The PDD/PD error pattern was characterized by relatively higher rates of commissions, an error type associated with reduced executive control. The AD error pattern was characterized by relatively higher rates of omissions, which have been associated with episodic memory failures (Giovannetti et al., 2006; Giovannetti, Bettcher, Brennan, Libon, Kessler, et al., 2008).

Between-group differences on performance-based tests of everyday action, as well as the results of the regression analyses, generally supported the Omission-Commission Model. This model posits that individuals with different neuropsychological impairments exhibit different patterns of EAI. Specifically, executive control deficits create difficulties in performing everyday tasks in an organized and efficient manner leading to mis-sequenced steps and inaccurate object/tool selection (i.e., commissions). This component of the model is generally consistent with accounts that emphasize the role of executive functions in efficient, goal-directed action (Buxbaum et al., 1997; Duncan, 1986; Fuster, 1989; Luria, 1966; Norman & Shallice, 1980; Sirigu et al., 1995). Another important component of the Omission-Commission Model proposes a unique role of episodic memory failures and degraded task knowledge on EAI, suggesting failure to recall or access task goals leads to the premature termination of the task and exclusion of major task components (i.e., omissions). The Omission-Commission Model contrasts with

Table 7. Summary of Hierarchical Regression Analysis for Variables Predicting Omissions ($N = 60$)

Variable	*B*	SE *B*	β
Step 1			
constant	48.89	6.18	
MMSE Total Score	−1.59	0.25	−.65*
Step 2			
constant	20.74	8.51	
MMSE Total Score	−0.43	0.35	−.18
Episodic Memory Composite	−5.67	1.55	−.50*
Executive Control Composite	−2.14	1.47	−.17

$R^2 = .42$ for Step 1 ($p < .01$); R^2 change = .15 for Step 2 ($p < .01$); *$p < .05$

previous work emphasizing the role of global level of cognitive impairment on everyday action error patterns (Bouwens, et al., 2008; Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Schwartz et al., 1998, 1999) or suggesting that diverse neuropsychological deficits lead to similar everyday action errors (Buxbaum et al., 1998; Hartmann et al., 2005). However, the model is consistent with several new reports showing differences in functional abilities across patients/populations with different dementia subtypes (Gure, Kabeto, Plassman, Piette, & Langa, 2010) or different forms of mild cognitive impairment (Bangen et al., 2010).

To be clear, general dementia severity remains important for understanding EAI, as global level of cognitive impairment was highly associated with the *degree* of functional impairment—the dementia groups (PDD, AD) exhibited significantly lower caregiver ratings and poorer global scores on performance-based functional tasks than the PD group. However, global cognitive impairment provides little information regarding the *pattern* of everyday action errors across the groups. Also, even after accounting for general dementia severity, neuropsychological measures of episodic memory and executive control explained additional variance in omission and commission scores, respectfully. In fact, episodic memory explained *significantly more* variance in Omissions than general dementia severity.

One important component of the Omission-Commission Model that was not evaluated in this study is the influence of

Table 8. Summary of Hierarchical Regression Analysis for Variables Prediction Commissions ($N = 60$)

Variable	*B*	SE B	β
Step 1			
constant	33.57	4.4	
MMSE Total Score	−0.92	0.18	−.57*
Step 2			
constant	26.48	6.76	
MMSE Total Score	−0.63	0.28	−.39**
Episodic Memory Composite	−0.06	1.23	−.01
Executive Control Composite	−2.45	1.16	−.29**

$R^2 = .33$ for Step 1 ($p < .01$); R^2 change = .06 for Step 2 ($p = .11$); *$p < .01$; **$p < .05$

[4] When regression analyses of omission/commission errors were performed using the DRS-2 Total and composite scores that excluded the DRS scales, results patterned similarly to those reported here. However, the effects were weakened to the trend-level, potentially due to the considerable overlap between the DRS-2 Initiation/Perseveration and Memory Scales and the Executive and Episodic Memory Composites, respectively.

task knowledge on everyday action error patterns. The link between degraded task knowledge and omission errors remains speculative (Bier & Macoir, 2011; Seter et al., 2010). Past studies have shown that AD patients exhibit impaired task knowledge when assessed independently from task execution (Cosentino et al., 2006; Grafman et al., 1991), but reports differ in terms of whether these knowledge deficits affect everyday action performance (Buxbaum et al., 1997). To our knowledge everyday task knowledge has not been empirically investigated in PDD, but investigators have reported relatively preserved task knowledge in PD (Zalla et al., 2000) and in participants with executive control deficits following frontal lobe injury (Sirigu et al., 1996). We speculate that degraded task knowledge associated with AD contributed to their omission error pattern and relatively preserved task knowledge in PD/PDD reduced the PD/PDD omission rate; however, further research is essential to fully appreciate the relation between task knowledge and EAI. Our laboratory is developing measures of task knowledge and refining intervention strategies to improve task knowledge (Bettcher et al., 2011), but there is currently little consensus on the optimal method for evaluating this form of semantic knowledge.

In the present study, action addition errors occurred relatively infrequently and were strongly correlated with commissions but not omissions. Thus, to simplify our statistical analyses in the face of a small sample, we combined commissions and additions into a single commission error category. Prior studies have not conclusively shown action additions to dissociate from either omissions or commissions and the neuropsychological correlates for additions remain unknown (Giovannetti, Bettcher, Brennan, Libon, Kessler, et al., 2008). The current results suggest that action additions are more strongly associated with the executive control deficits that are linked to commissions, such as increased distractibility and off-task behaviors. Further research, possibly using experimental paradigms that offer a greater opportunity for additions or clinical populations with high rates of addition errors (e.g., schizophrenia; Kessler et al., 2007) is necessary before drawing firm conclusions regarding the nature of this error type.

PDD caregivers reported participants to be less independent in daily activities than AD caregivers, even though the groups showed a comparable level of dementia severity and comparable overall impairment on performance-based global measures. There are numerous possible explanations for this finding. It is possible that caregiver ratings are influenced by different forms of EAI, with high rates of commissions and/or long task completion times leading to reports of greater dependence. When these performance-based variables were included individually as covariates in the analysis comparing PDD versus AD participants on caregiver ratings, only the Time to Completion variable made the difference nonsignificant ($p = .32$), suggesting that slowed performance times may differentially influence caregiver reports. We acknowledge, however, that other participant factors that were not measured also could have influenced the caregiver ratings, including affect, initiation, motivation, and so on. We also considered that caregiver reports reflect caregivers' *perceptions* of performance in the home, which may be influenced by caregiver mood and distress (Zanetti, Geroldi, Frisoni, Bianchetti, & Trabucchi, 1999). Unfortunately, we did not collect information on caregiver characteristics and are unable to offer a deep understanding of the difference in caregiver reports across the AD and PDD groups. However, this finding underscores the fact that caregiver reports and performance-based measures yield unique information and should be used jointly for the comprehensive assessment of EAI.

Along this line, it is important to note that our performance-based measures of everyday action focused on the *cognitive* contributions of everyday functioning, whereas caregiver ratings were not limited to the cognitive aspects of functional abilities. Performance-based scoring criteria purposefully focused on cognitive difficulties and did not include ratings for physical limitations or motor deficits (Schwartz et al., 2002, 2003). After controlling for global cognitive functioning (MMSE), relations between the UPDRS Motor Exam Score and performance-based measures of overall functioning were weak and nonsignificant ($n = 40$[5]; $r < .19$ for all).

Our findings lay the groundwork for future studies designed to explore whether differential everyday error patterns have meaningful implications for intervention. The Omission-Commission Model suggests that omissions may be prevented by interventions that promote recall and access of task goals (Bettcher et al., 2011; Bickerton, Humphreys, & Riddoch, 2006; Brennan, Giovannetti, Libon, Bettcher, & Duey, 2009; Bozeat, Patterson, & Hodges, 2004; Sartori, Miozzo, & Job, 1994). Interventions designed to improve task organization by imposing greater environmental structure (Giovannetti, Libon, et al., 2007; Gitlin, Corcoran, Winter, Boyce, & Hauk, 2001) or by promoting task monitoring (Levine et al., 2000, 2007; Manly, Hawkins, Evans, Woldt, & Robertson, 2002; Robertson, 1996) may be most beneficial for EAI characterized by high rates of commissions, particularly among dementia participants whose commissions are largely comprised of sequence and substitution errors. However, the clinical implications of the Omission-Commission Model have not been empirically tested. There is relatively little work showing benefit from one functional intervention strategy over another in any patient population, despite that the notion of matching deficits to treatment approach makes theoretical sense and has been proven to be the most prudent intervention strategy for other complex disorders, including amnesia and aphasia (Riddoch & Humphreys, 1994; Sohlberg & Mateer, 2001; Wilson, 1999).

We acknowledge several limitations of our study and highlight several strengths. First, our sample size was relatively small, decreasing our power to detect small but potentially meaningful differences between our groups. Replication with larger samples is essential; future work also might focus on the functional deficits associated with PD as well as potential functional differences between PDD and DLB. Second, a more comprehensive evaluation of participants (e.g., UPDRS Motor Exam data on AD participants)

[5] UPDRS Motor Examinations were performed only for PDD and PD participants.

and caregivers (e.g., mood, burden, etc.) would have allowed us to address several questions that were generated by our results on caregiver ratings. Third, our caregiver report measure, although widely used in the literature, provided information on only the global level of dependence on a set of tasks. In future research, we will incorporate newer caregiver measures that provide more detailed information on everyday functioning (Farias et al., 2008; Hobson, Edwards, & Meara, 2001). Neuropsychological tests were selected on the basis of the Omission-Commission Model and prior research; measures of other constructs, including other executive processes (e.g., planning, concept formation) and other measures of the same constructs should be considered in future research. With respect to strengths, this study used a comprehensive evaluation of everyday action, including caregiver reports as well as detailed, performance-based methods. Comparisons were made across groups that differed in terms of their clinical diagnosis/neuropsychological profile, which allowed for more nuanced conclusions regarding everyday action impairment in PDD.

In conclusion, this study revealed that EAI in PDD differed quantitatively from action impairment in PD and qualitatively from EAI in AD. This supports the basic notion that clinical populations with different neuropsychological profiles show different patterns of EAI. Moreover, the nature of the error patterns across the groups supported the Omission-Commission Model, which posits a link between executive control deficits and commissions and between episodic memory deficits (and degraded task knowledge) and omissions. These results underscore the importance of detailed performance-based assessment of functioning in the clinic and specify targets for future interventions.

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