Complex Task Performance Assessment (CTPA) and Functional Cognition in People With Parkinson's Disease

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OBJECTIVE. The objective of this study was to determine how Parkinson's disease (PD) affects functional cognition as assessed by the Complex Task Performance Assessment (CTPA) and to examine the associations of CTPA performance with other indicators of executive function in people with PD.

METHOD. Volunteers with PD without dementia ($n = 20$) and community control participants ($n = 19$) completed neuropsychological testing, patient-reported outcome measures, and the CTPA.

RESULTS. There were no group differences for CTPA performance accuracy; however, the PD group took longer to complete the CTPA than did the control group. In the PD group, inefficient CTPA performance correlated with poorer cognitive flexibility and worse reported everyday shifting and task monitoring.

CONCLUSION. Decreased executive function, namely cognitive flexibility and attentional control, may impair functional cognition in people with PD. Future studies with larger, more diverse samples are warranted to determine the discriminant validity and sensitivity of the CTPA. Use of performance-based assessments such as the CTPA may increase the understanding of functional cognition in people with PD.

Executive dysfunction among people with Parkinson's disease (PD) without dementia is associated with decreased activities of daily living function, quality of life, and participation (Foster & Hershey, 2011; Klepac et al., 2008; Rosenthal et al., 2010). Executive function encompasses higher order cognitive processes (e.g., problem solving, cognitive flexibility) needed for engaging in independent, purposeful, and goal-directed behaviors essential for completing daily activities (Suchy, 2009). Neuropsychological tests have revealed much about the nature of executive dysfunction among people with PD without dementia (Muslimovic et al., 2005). However, the highly structured and abstract nature of these tests limits their ability to represent and predict cognitive performance in real-world situations (i.e., their ecological validity; Burgess et al., 2006; Chaytor & Schmitter-Edgecombe, 2003).

To address this limitation, patient-reported outcome measures (PROs) are increasingly used to provide insight into the real-world effects of PD-related cognitive dysfunction (Foster & Hershey, 2011; Koerts, Van Beilen, Tucha, et al., 2011). However, there are potential limitations to using PROs within the PD population. For example, PD-related depression and cognitive decline have been associated with inconsistencies between self-reported and objective function (Koerts, van Beilen, Leenders, et al., 2011; Shulman et al., 2006). Thus, neither neuropsychological tests nor PROs are entirely suitable for providing information on *functional cognition*—the ability to use and integrate thinking and processing skills to accomplish complex everyday activities (Giles & Wolf, 2017; Young et al., 2010)—in people with PD. This information is critical to the development or identification of interventions to address PD-related cognitive impairment and support occupational performance and participation.

Objectively assessing complex, cognitively demanding activity performance with standardized performance-based assessments may contribute to the understanding of functional cognition in people with PD. These performance-based

assessments are less structured (e.g., ambiguous goals, open-ended questions, multiple possible solutions), simulate real-world activities (e.g., medication management, cooking), and use real-world materials (e.g., pill organizers, stoves). These features greatly enhance their face validity, which should improve their ecological validity (Chaytor & Schmitter-Edgecombe, 2003). Moreover, such assessments can identify changes in functional cognition in people with neurological conditions when neuropsychological test scores indicate minimal to no impairment (Goldberg et al., 2010; Moore et al., 2007).

One example of such an assessment is the Complex Task Performance Assessment (CTPA; Wolf et al., 2008). The CTPA simulates a complex real-life activity involving cognitively demanding clerical work that requires multitasking, attentional control, and problem solving (Wolf et al., 2008). The purpose of this study was to investigate functional cognition in people with PD using the CTPA. We selected the CTPA because it is clinically feasible; was designed to evaluate complex activity performance in people with subtle executive dysfunction; and was found to be reliable, valid, and sensitive to impaired functional cognition in people with mild stroke (Wolf et al., 2008, 2015). We administered the CTPA and neuropsychological tests and PROs of executive function to people with PD without dementia and control participants. We hypothesized that the participants with PD would have impaired CTPA performance compared with control participants and that their CTPA performance would correlate with neuropsychological tests and PROs of executive function.

Method

Participants

Participants were volunteers with PD and age-matched community control (CC) participants. Participants with PD were recruited through the Washington University School of Medicine (WUSM) Movement Disorders Center (MDC), and their significant others were convenience sampled as controls to facilitate matching. Additional control participants were recruited through the WUSM Research Participant Registry and advertisement flyers. Participants with PD were diagnosed with typical idiopathic PD and classified as Stage I–III (I = unilateral involvement only; II = bilateral or midline involvement without impaired balance; III = mild to moderate bilateral disease, some postural instability, and physically independent; Hoehn & Yahr, 1967). Exclusion criteria included dementia or possible mild cognitive impairment (physician report or score ≤ 25 on the Montreal Cognitive Assessment [MoCA]; Dalrymple-Alford et al., 2010; Litvan et al., 2012), neurological condition other than PD for participants with PD (e.g., stroke), current significant psychiatric symptoms (e.g., severe depression) or history of psychosis, inability to comprehend instructions, or any other condition that would interfere with testing (e.g., severe dyskinesia). Additional exclusion criteria for the control group included presence of or a first-degree relative with PD.

Research Design and Procedure

The Human Research Protection Office at Washington University in St. Louis approved this study. All participants provided written informed consent. This was a cross-sectional observational study. Participants completed questionnaires via a Web-based survey (Harris et al., 2009) at home before their scheduled appointment to take the MoCA, National Institutes of Health Toolbox Cognition Battery (NIH–CB), and CTPA (always in that order) during an in-person appointment in a private testing room at the WUSM MDC. PD-related clinical characteristics (e.g., medications; disease duration; motor dysfunction severity, measured by the Unified Parkinson's Disease Rating Scale Motor subscale [UPDRS–III; Goetz et al., 2007]) were obtained from clinical records.

Measures

Complex Task Performance Assessment.

The CTPA simulates working in a library (described in detail in Wolf et al., 2008). The two primary tasks are current inventory control and telephone messages. For current inventory control, participants calculate the total fine and

replacement cost for books and videos that are overdue. For telephone messages, participants listen to recorded telephone messages and respond according to the content of the message. Participants also complete two prospective memory tasks (one event-based and one time-based task) during the test. Performance is timed. After receiving instructions and before beginning the assessment, participants are required to recite all task requirements and rules to establish comprehension.

CTPA performance is scored in four categories: inefficiencies, rule breaks, interpretation failures, and task failures (Shallice & Burgess, 1991). Inefficiencies occur when participants could have implemented a more effective strategy to complete the task (e.g., did not sort cards by title before starting). Rule breaks occur when participants break social rules or specific rules of the CTPA (e.g., spoke to the experimenter other than as indicated by the rules). Interpretation failures occur when participants misinterpret what was expected or required to complete the task (e.g., identifying inaccurate fines). Task failures occur when participants do not attempt or complete a required task (e.g., the inventory control sheet). A point is given for each error committed. Inventory control sheet accuracy is scored by summing the incorrect items (out of 15 possible). The CTPA total score is the sum of the number of inefficiencies, rule breaks, interpretation failures, and task failures and the inventory control sheet score. Higher scores indicate poorer performance. The CTPA demonstrated high interrater reliability ($r_s \geq .89$) and acceptable concurrent validity in a study of community controls and participants with mild stroke (Wolf et al., 2015).

National Institutes of Health Toolbox Cognition Battery.

The NIH-CB consists of computerized cognitive tests and has been normed and determined reliable, sensitive, and valid across the lifespan (Weintraub et al., 2013). It includes the Dimensional Change Card Sort (DCCS; cognitive flexibility), Flanker (inhibitory control), Picture Sequence Memory (visual episodic memory), Picture Vocabulary (language, vocabulary), Oral Reading Recognition (language, reading), List Sorting (working memory), and Pattern Comparison (processing speed) tests (Weintraub et al., 2013). Crystallized Cognition (cognitive abilities more dependent on past learning experiences), Fluid Cognition (capacity to learn and process information in novel situations), and Cognitive Function Composite scores can be calculated to provide reliable indexes of function in those broad cognitive domains (Gershon et al., 2010). Age-corrected scores are reported (mean [M] = 100, standard deviation [SD] = 15), with higher scores indicating better performance.

Dysexecutive Questionnaire and Behavior Rating Inventory of Executive Function–Adult Version.

The Dysexecutive Questionnaire (DEX) includes 20 items on dysexecutive behaviors in everyday life (Burgess et al., 1998). Participants rate items according to how often they experience the behavior on a 5-point scale (from 0 = *never* to 4 = *very often*), and items are summed for a total score. Higher scores indicate worse reported everyday executive function. The overall reliability of the DEX is high ($r = .85$; Bodenburg & Dopsch, 2008). The Behavior Rating Inventory of Executive Function–Adult Version (BRIEF–A), a 75-item questionnaire of everyday behaviors in specific domains of executive function, demonstrates good reliability and validity in healthy and neuroclinical populations (Roth et al., 2005). It consists of the Behavioral Regulation Index, which includes Inhibit, Shift, Emotional Control, and Self-Monitor scales, and the Metacognition Index, which includes Initiate, Working Memory, Plan/Organize, Task Monitor, and Organization of Materials scales. It reports t scores ($M = 50$, $SD = 10$), with higher scores indicating worse reported everyday executive function.

Statistical Analysis

Study data were stored and managed using research electronic data capture, or REDCap, tools (Harris et al., 2009) hosted at Washington University in St. Louis and analyzed using IBM SPSS Statistics (Version 23; IBM Corp., Armonk, NY). Descriptive statistics were calculated for all variables. Because of the small sample and nonnormal distributions

of CTPA data, nonparametric analyses were used (Mann–Whitney U test, Spearman's ρ). Between-group effect sizes (r) were also calculated for the CTPA (Gignac & Szodorai, 2016). All tests were two-tailed, and $p < .05$ was considered significant. On the basis of data from a study of mild stroke (Wolf et al., 2015), a group size of 13 participants was determined to be sufficient for detecting group differences in CTPA total score (80% power, $\alpha = .05$). Because we were testing a different population than that in Wolf et al. (2015) and to account for potential attrition, the target sample for this study was 20 participants per group.

Results

Participant Characteristics

The sample included 20 participants with PD and 19 CC participants (Table 1). There were no significant group differences in gender, race, ethnicity, age, education, work status, or MoCA score ($p \geq .16$). Beck Depression Inventory–II (BDI–II) scores were higher in the PD group ($Z = -3.19$, $p = .001$) but still indicated only minimal depressive symptoms.

Group Comparisons

Participants with PD took a longer time than CC participants to complete the CTPA, $Z = -2.66$, $p = .008$ (Table 2). There were no group differences for any of the other CTPA scores ($p \geq .14$), and all effect sizes were in the small to medium

range. All of the PD and CC group average scores were within (or above) the normal range for all of the NIH–CB tests (Table 3) and BRIEF–A domains (Table 4). The PD group had poorer BRIEF–A Plan/Organize, Initiate, and Metacognition Index scores than the CC group ($p \leq .013$). There were no other group differences for these measures ($p \geq .06$).

Within-Group Associations

For the PD group, CTPA Inefficiency scores correlated with NIH–CB DCCS ($r_s = -.52$, $p = .02$) and Fluid Cognition Composite scores (trend level; $r_s = -.41$, $p = .07$), such that less efficient CTPA performance was associated with poorer cognitive flexibility and overall executive function performance. For the CC group, CTPA rule breaks correlated with NIH–CB Picture Sequence Memory and Cognitive Function Composite scores ($r_s = -.48$, $p = .04$ and $r_s = -.52$, $p = .02$), such that more CTPA rule breaks were associated with poorer memory and overall cognitive performance.

For the PD group, CTPA Inefficiency scores correlated with BRIEF–A Shift and Task Monitor scores ($r_s = .58$, $p = .008$ and $r_s = .45$, $p = .047$), such that less efficient CTPA performance was associated with worse reported everyday shifting

Table 1. Characteristics of Parkinson's Disease ($n = 20$) and Community Control ($n = 19$) Groups

Characteristic	PD Group, n or $M(SD)$	CC Group, n or $M(SD)$
Male/female ratio	11/9	7/12
Age, yr	63.40 (7.84)	62.68 (9.48)
Race		
White	20	17
African-American	0	2
Ethnicity		
Hispanic/Latino	0	1
Not Hispanic/Latino	20	16
Declined to state	0	2
Education level		
Some college	1	5
College graduate	6	10
Postgraduate	13	4
Work status		
Work outside home	5	8
Retired	13	9
Disabled/other	2	2
MoCA score	28.30 (1.59)	27.47 (1.95)
BDI–II score*	6.90 (5.65)	2.21 (3.24)
UPDRS–III Motor subscale score (participants on medications)	15.65 (9.03)	—
Hoehn and Yahr stage		
I	3	—
II	15	—
III	2	—

Note. BDI = Beck Depression Inventory; CC = community control; M = mean; MoCA = Montreal Cognitive Assessment; PD = Parkinson's disease; SD = standard deviation; UPDRS = Unified Parkinson's Disease Rating Scale; — = not applicable.

*PD > CC, $p = .001$.

Table 2. Group Comparison and Between-Group Effect Sizes of Complex Task Performance Assessment Scores

Category and Group	<i>M</i> (<i>SD</i>)	Median	Range	<i>r</i>
Inefficiencies				
PD	0.20 (0.52)	0.00	0–2	.18
CC	0.05 (0.23)	0.00	0–1	
Rule breaks				
PD	0.50 (0.95)	0.00	0–3	.15
CC	0.26 (0.65)	0.00	0–2	
Interpretation failures				
PD	2.65 (2.76)	2.00	0–9	–.06
CC	2.95 (2.14)	3.00	0–6	
Task failures—did not attempt				
PD	0.00 (0.00)	0.00	0–0	–.24
CC	0.11 (0.32)	0.00	0–1	
Task failures—stated complete				
PD	0.15 (0.50)	0.00	0–2	.21
CC	0.00 (0.00)	0.00	0–0	
Task failures—time limit reached				
PD	0.20 (0.52)	0.00	0–2	.10
CC	0.11 (0.32)	0.00	0–1	
Incorrect/blank items on inventory control				
PD	5.50 (15.10)	4.00	0–15	–.10
CC	6.26 (2.10)	6.00	2–10	
Total score				
PD	9.35 (7.40)	7.50	0–25	–.04
CC	9.84 (3.52)	11.00	3–18	
Total time, min*				
PD	36.10 (14.10)	31.50	62–82	.29
CC	28.26 (11.96)	25.00	48–63	

Note. CC = community controls; *M* = mean; PD = Parkinson's disease; *SD* = standard deviation.

*PD > CC, $p = .008$.

and task monitoring. There were no other significant correlations between the PROs in either group ($p \geq .14$).

For the PD group, NIH–CB Cognitive Function Composite scores correlated with BRIEF–A Behavioral Regulation Index scores ($r_s = -.45$, $p = .05$), such that better overall NIH–CB performance was associated with better reported behavioral regulation. For the CC group, NIH–CB Picture Sequence Memory scores correlated with BRIEF–A Emotional Control scores ($r_s = -.58$, $p = .009$), such that better memory performance was associated with better reported emotional control.

Follow-Up Analyses

A series of follow-up analyses explored possible explanations for our findings. We correlated UPDRS–III and BDI–II with our cognitive measures to investigate the potential influence of PD-related motor dysfunction and depressive symptoms. UPDRS–III did not correlate with any cognitive variables ($p \geq .16$). However, BDI–II correlated with CTPA Inefficiency ($r_s = .48$, $p = .03$) and most of the BRIEF–A scales ($r_s \geq .45$, $p \leq .05$), such that more depressive symptoms were associated with less efficient CTPA performance and worse reported everyday executive function. Given this finding, we

conducted partial correlations between the CTPA and BRIEF–A, controlling for BDI–II. The correlation between CTPA Inefficiency and BRIEF–A Shift remained significant ($r_s = .46$, $p = .05$), but the correlation between CTPA Inefficiency and Task Monitor did not.

To explore the potential sensitivity of the CTPA to changes in functional cognition in the absence of impaired neuropsychological test performance, we excluded the 2 participants with PD who scored ≥ 1 *SD* below the mean on the NIH–CB Fluid Cognition Composite (no CC participants fell below this cutoff) and reran our primary analyses. The PD group still took longer to complete the CTPA than the CC group ($Z = -2.42$, $p = .016$) and had

Table 3. Group Comparison of National Institutes of Health Toolbox Cognition Battery Scores

Test	PD Group, <i>M</i> (<i>SD</i>)	CC Group, <i>M</i> (<i>SD</i>)
Picture Vocabulary	117.50 (9.70)	113.95 (11.03)
Flanker	89.30 (12.32)	92.47 (9.02)
List Sorting	112.45 (15.06)	110.89 (14.54)
Dimensional Change Card Sort	105.05 (16.54)	105.79 (10.90)
Pattern Comparison	92.65 (18.68)	97.95 (12.84)
Picture Sequence Memory	104.60 (12.88)	104.21 (16.58)
Oral Reading Recognition	119.00 (13.56)	119.89 (13.09)
Fluid Cognition Composite	101.70 (11.93)	104.26 (8.60)
Crystallized Cognition Composite	119.45 (11.39)	117.68 (12.59)
Cognitive Function Composite	112.10 (10.94)	112.74 (9.61)

Note. All scores are age adjusted. CC = community controls; *M* = mean; PD = Parkinson's disease; *SD* = standard deviation.

poorer BRIEF–A Plan/Organize, Initiate, and Metacognition Index scores ($p \leq .02$). In addition, CTPA Inefficiency correlated with NIH–CB DCCS and Flanker ($r_s = -.64$, $p = .004$ and $r_s = -.47$, $p = .047$, respectively) and with BRIEF–A Shift and Task Monitor (trend level; $r_s = .59$, $p = .009$ and $r_s = .44$, $p = .06$, respectively).

Table 4. Group Comparison of Dysexecutive Questionnaire and Behavioral Rating Inventory of Executive Function–Adult Version Scores

Measure	PD Group, <i>M</i> (<i>SD</i>)	CC Group, <i>M</i> (<i>SD</i>)
DEX	9.65 (6.81)	7.05 (5.56)
BRIEF–A		
Inhibit	47.05 (5.08)	47.05 (7.32)
Shift	47.55 (7.73)	44.53 (6.23)
Emotional Control	45.20 (6.29)	43.89 (6.81)
Self-Monitor	42.65 (5.94)	45.63 (9.28)
Initiate*	52.45 (9.32)	43.58 (7.31)
Working Memory	52.40 (11.74)	47.32 (8.93)
Plan/Organize*	48.65 (8.91)	43.00 (4.50)
Task Monitor	51.35 (9.43)	46.11 (7.77)
Organization of Materials	49.25 (9.24)	44.95 (6.29)
Behavioral Regulation Index	44.50 (5.25)	44.00 (7.62)
Metacognition Index*	50.55 (10.19)	43.79 (6.79)
Global Executive Composite	47.80 (7.90)	43.58 (6.99)

Note. All scores are scaled scores. BRIEF–A = Behavioral Rating Inventory of Executive Function–Adult Version; CC = community controls; DEX = Dysexecutive Questionnaire; *M* = mean; PD = Parkinson's disease; *SD* = standard deviation.

*PD > CC, $p < .05$.

Discussion

We investigated PD-related changes in functional cognition as assessed by the CTPA and evaluated the relationship between CTPA performance and other measures of executive function in people with PD. We administered the CTPA and neuropsychological tests and PROs of executive function to people with PD without dementia and control participants. Performance in both groups was high for all administered measures, which is unsurprising because the sample consisted of mostly college-educated, independent, community-dwelling adults with MoCA scores in the normal range. Despite similar accuracy on the CTPA, the PD group took longer to complete the task. In addition, in the PD group, CTPA performance related to some aspects of executive function as measured by neuropsychological tests and PROs.

The PD group's average time to complete the CTPA approached the published clinical cutoff (40 min). This slower performance may indicate more difficulty with the

task and is clinically significant because it may reflect or predict increased time required to perform activities in daily life (Foster, 2014; Thordardottir et al., 2014). Moreover, it may be a precursor to eventual decline in accuracy of activity performance.

Our correlational analysis suggests that this inefficient performance may be attributed to executive dysfunction because participants with PD with less efficient CTPA performance also had poorer task monitoring and cognitive flexibility. Inefficient CTPA performance occurs when a participant's approach results in increased time required to complete the task or a higher likelihood of errors than if a different approach were taken (Wolf et al., 2008). It indicates that the participant is not appropriately monitoring and adjusting his or her performance to be more effective. These cognitive processes are some of the earliest to be affected by PD (Cools, 2006). Alternatively, it may reflect motor impairment or slowed cognitive processing (Rafal et al., 1984). However, this explanation seems less likely because neither motor dysfunction nor processing speed was related to CTPA performance in this sample.

Our findings are inconsistent with a previous study, which found that people with mild stroke obtained significantly lower CTPA scores than healthy community controls (Wolf et al., 2015). Other than the PD group's increased time taken to complete the CTPA in the current study, its task performance was equivalent to the matched control group. People with mild stroke and early PD have executive dysfunction (see Muslimovic et al., 2005; Wolf et al., 2011). However, it is clear from the relatively high scores (equivalent to those of the healthy control group) on the CTPA, NIH–CB, and PROs of the PD group that they had much more subtle executive dysfunction than the mild stroke sample in Wolf et al. (2015). In addition, they had higher education and a different racial profile, which may have contributed to differences between studies because education and other sociodemographic variables have been shown to influence performance on executive function tests (Campanholo et al., 2017).

Limitations of this study include use of a small, somewhat nonrepresentative sample. In addition to high cognitive abilities, our PD sample was highly educated, had high socioeconomic status, and had mild disease severity. A larger, more diverse sample that included people with possible mild cognitive impairment may have resulted in more variable CTPA performance, a better test of the CTPA's discriminant validity for people with PD and sensitivity to functional cognitive impairment, and more power to detect clinically meaningful effects.

Despite the limitations of our sample, we found that participants with PD required increased time to complete the CTPA and that their ability to monitor their performance to identify and correct errors on the CTPA was related to cognitive flexibility and attentional control. These findings could not be explained by motor dysfunction or depressive symptoms, although depressive symptoms may play a role. Moreover, these findings held in the subset of participants considered to have “normal” executive function according to neuropsychological tests and PROs. Thus, the CTPA detected subtle PD-related cognitive changes not identified through other modes of cognitive assessment.

Implications for Occupational Therapy Practice

This study has the following implications for occupational therapy practice:

- To provide comprehensive clinical care to people with PD, occupational therapy practitioners should consider and address functional cognition.
- Standardized performance-based assessments of cognitively complex real-life activities, such as the CTPA, may contribute to the understanding of functional cognition in people with PD.
- Occupational therapy practitioners should be aware that high-functioning and physically independent people with PD may experience subtle occupational performance problems as a result of executive dysfunction.
- Administering the CTPA may permit occupational therapy practitioners to detect deficits in functional cognition.

Conclusion

Our results suggest that even early in PD and in the absence of obvious cognitive decline, deficits in executive function may negatively affect the efficiency with which people with PD perform complex, cognitively demanding activities. More research is needed to support the use of the CTPA in clinical practice with individual clients, including determining contributing factors (e.g., depressive symptoms), cutoff scores to indicate impaired functional cognition, and sensitivity to very subtle cognitive deficits. Still, our findings suggest that incorporating performance-based assessments of functional cognition such as the CTPA in PD-related rehabilitation research and practice may help identify people at risk for activity limitations in everyday life and reveal the nature of those limitations. This information could then guide the selection or development of interventions to address functional cognition and ultimately support occupational performance, participation, and quality of life for people with PD. ■

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