Journal of the International Neuropsychological Society (2024), **30**, 370–379
doi:10.1017/S1355617723000620

Research Article

Perception of cognitive change by individuals with Parkinson's disease or essential tremor seeking deep brain stimulation: Utility of the cognitive change index

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Abstract

Objective: The Cognitive Change Index (CCI-20) is a validated questionnaire that assesses subjective cognitive complaints (SCCs) across memory, language, and executive domains. We aimed to: (a) examine the internal consistency and construct validity of the CCI-20 in patients with movement disorders and (b) learn how the CCI-20 corresponds to objective neuropsychological and mood performance in individuals with Parkinson's disease (PD) or essential tremor (ET) seeking deep brain stimulation (DBS). **Methods:** 216 participants ($N = 149$ PD; $N = 67$ ET) underwent neuropsychological evaluation and received the CCI-20. The proposed domains of the CCI-20 were examined via confirmatory (CFA) and exploratory (EFA) factor analyses. Hierarchical regressions were used to assess the relationship among subjective cognitive complaints, neuropsychological performance and mood symptoms. **Results:** PD and ET groups were similar across neuropsychological, mood, and CCI-20 scores and were combined into one group who was well educated ($m = 15.01 \pm 2.92$), in their mid-60's ($m = 67.72 \pm 9.33$), predominantly male (63%), and non-Hispanic White (93.6%). Previously proposed 3-domain CCI-20 model failed to achieve adequate fit. Subsequent EFA revealed two CCI-20 factors: memory and non-memory ($p < 0.001$; CFI = 0.924). Regressions indicated apathy and depressive symptoms were associated with greater memory and total cognitive complaints, while poor executive function and anxiety were associated with more non-memory complaints. **Conclusion:** Two distinct dimensions were identified in the CCI-20: memory and non-memory complaints. Non-memory complaints were indicative of worse executive function, consistent with PD and ET cognitive profiles. Mood significantly contributed to all CCI-20 dimensions. Future studies should explore the utility of SCCs in predicting cognitive decline in these populations.

Keywords: Movement disorders; Factor analysis; Statistical; Cognitive dysfunction; Depression; Anxiety; Apathy

(Received 14 June 2023; final revision 28 August 2023; accepted 6 September 2023; First Published online 6 October 2023)

Introduction

The overarching goal of the current study was to examine the utility of a questionnaire for assessing subjective cognitive complaints (SCCs) in individuals with Parkinson's disease (PD) and essential tremor (ET). The rationale for doing so was threefold. First, these two movement disorders are the most common movement disorders in the world, affecting nearly 8.5 million (PD) and 25 million (ET) individuals worldwide (Song et al., 2021; World Health Organization, 2022). Second, both disorders are associated with cognitive sequelae in addition to progressive motor symptoms. In fact, individuals with PD and ET exhibit an increased risk of developing mild cognitive impairment (MCI) and eventually dementia relative to healthy controls (Åström et al., 2022; Thawani et al., 2009). Currently, 20–24% of ET patients meet criteria for MCI compared to 16% in the general population (Benito-León et al., 2011; Ratajska, Lopez, et al., 2022). In PD, the prevalence of MCI is greater, 39.6% overall and 31.7% among newly diagnosed patients (Nicoletti et al., 2019). Moreover, approximately 80% of individuals with PD meet criteria for dementia after 15–20 years of disease duration (Hely et al., 2008). Third, identification of individuals at increased risk for MCI and dementia is critical for implementation of interventions aimed at maximizing brain health and ameliorating cognitive decline. These three reasons provide the groundwork for the current study, which focused on the construct validity of a questionnaire for identifying SCCs in individuals with PD or ET.

While both PD and ET are "movement disorders," they differ in terms of pathophysiology and clinical presentation. The motor symptoms of PD stem from alpha synuclein-driven neurodegeneration of the substantia nigra, which provides dopaminergic input to subcortical and cortical areas (Damier et al., 1999; Dickson,

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Cite this article: Rodriguez K., Schade R.N., Lopez F.V., Kenney L.E., Ratajska A.M., Gertler J., & Bowers D. (2024) Perception of cognitive change by individuals with Parkinson's disease or essential tremor seeking deep brain stimulation: Utility of the cognitive change index. *Journal of the International Neuropsychological Society*, **30**: 370–379, https://doi.org/10.1017/S1355617723000620

2018); this results in resting tremors, slowness, rigidity, and postural-gait changes. Relatedly, PD-linked cognitive changes (slowness, executive dysfunction) have largely, but not exclusively, been associated with dopaminergic depletion of frontal lobe systems, though other neurotransmitter systems are involved in the PD cognitive profile as well (Halliday et al., 2014; Owen et al., 1992; Rodriguez-Oroz et al., 2009). In contrast, the motor symptoms of ET largely involve "action" tremors of the hands, voice, and head, and stem from an anomaly in cerebellar-thalamic-frontal networks. Like PD, the cognitive sequelae of ET largely reflects executive dysfunction. Recent studies have highlighted the cognitive and mood similarities of PD and ET, including the patterns of MCI associated with each (Kenney et al., 2021; Lafo et al., 2015; Ratajska, Scott, et al., 2022).

In 2012, the Movement Disorders Society assembled a task force which outlined diagnostic criteria for MCI. These criteria included: (1) presence of a subjective cognitive complaint, (2) absence of significant functional impairment due to cognitive difficulties, and (3) evidence of cognitive deficits on at least two standardized neuropsychological tests (Litvan et al., 2011). Inclusion of SCCs in the diagnostic criteria for MCI is not a novel concept (see Petersen et al., 1999) as many individuals begin noticing subtle cognitive changes prior to detection of poor performance on standardized cognitive tests. In fact, the trajectory of atypical cognitive decline begins with 'silent brain changes' which may be noticed by an individual and expressed via SCCs (see Saykin et al., 2006). Yet, there are no specific recommendations or validated scales for SCCs in ET or PD.

Over 34 questionnaires have been developed to measure SCCs in older adults (Rabin et al., 2015). These vary along numerous dimensions ranging from length, types of cognitive domains assessed, targeted population, to psychometric properties. Rabin and colleagues (2015) established the Subjective Cognitive Decline Initiative (SCD-I) Working Group which provided recommendations for instrument selection and operationalization. Relevant recommendations included: selection of instruments with sufficient cognitive domain content coverage for the target population, assessment of instruments for psychometric adequacy, inclusion of items related to mood, personality, and overall health, and consideration of demographic factors. Given the lack of instruments specific to movement disorder populations and the potential confounding influence of mood factors on SCCs, the working group suggested future research ensure that measures are validated in the population of interest and include mood-related variables so to explain as much unique variance as possible.

To determine whether an existing multidomain scale would be appropriate for quantifying cognitive complaints in a movement disorders sample, we administered the Cognitive Change Index (CCI-20) to individuals with PD and ET who were being seen for clinical care at the University of Florida (UF). We selected the CCI-20 because it asks questions about multiple cognitive domains (memory, executive, language) which are known to be affected in patients with PD and ET (Kenney et al., 2021; Ratajska, Lopez, et al., 2022) and because of its link to "silent brain changes" (i.e., hippocampal volume) in older adults with normal cognition (Saykin et al., 2006). The CCI-20 was originally developed by Rattanabannakit and colleagues (2016) based on findings by Saykin et al. (2006) that SCCs in cognitively normal older adults were associated with reduced hippocampal gray matter density. The 20 items of this questionnaire were adapted from a larger item pool and rationally selected based on the assumption that they measured functioning in three cognitive domains: memory, executive, and language. Despite its multidomain structure, previous research has not assessed the CCI-20 for internal consistency reliability or construct validity in a movement disorders sample.

The current study had two aims. Aim 1 examined whether the three cognitive domains of the CCI-20 (i.e., memory, executive, and language) were psychometrically present in a movement disorders population, in line with the domains proposed for older adults (Rattanabannakit et al., 2016). Aim 2 investigated the relationship between SCCs as indexed by the CCI-20 and objective performance on neurocognitive and mood/motivation measures in patients with PD or ET. This aim helped shed light on concerns that subjective cognitive complaints may primarily be driven by mood and psychological symptoms (Barbosa et al., 2019; Chua et al., 2021; Edmonds et al., 2014; Lehrner et al., 2014; Smit et al., 2021).

Methods

Participants and procedure

Participants included a convenience sample of 216 patients with idiopathic PD or ET who underwent neuropsychological evaluation at the UF Norman Fixel Institute between 2019 and 2021. The evaluation was completed as part of a standard interdisciplinary pre-surgical workup for potential deep brain stimulation (DBS) surgery. All participants had been clinically diagnosed with either PD or ET by fellowship-trained movement disorders specialists based on the UK Parkinson's Disease Society Brain Bank Diagnostic Criteria for PD (Hughes et al., 1992) or the Louis criteria for ET (Louis et al., 1998). Exclusion criteria included: (a) missing neuropsychological measures used in the study ($n = 4$) and (b) missing CCI-20 itemized scores ($n = 45$). Thus, 49 participants were excluded for a final N of 216 participants. All participants provided written, informed consent in accordance with University of Florida IRB guidelines and the Declaration of Helsinki.

As part of the neuropsychological workup, participants first completed the CCI-20, followed by a 2–3-hour neuropsychological exam consisting of cognitive and mood/motivation measures. Disease-related characteristics included scores on movement rating scales and disease duration that took place during the patients' most recent neurological examinations, typically within 1–2 months of testing. All components of the evaluation, including movement ratings, were conducted while participants were "on" their normal doses of dopamine and other medications.

Measures

Cognitive Change Index (CCI-20)

The CCI-20 is a 20-item questionnaire that asks participants to rate their current cognitive functioning compared to 5 years ago. Items are rated on a 5-point Likert scale (1 = no change or normal ability, 2 = minimal change or slight/occasional problem, 3 = some change or mild problem, 4 = clearly noticeable change or moderate problem, and 5 = much worse or severe problem). The first 12 items are in the memory domain (e.g., "remembering names and faces of new people I meet"), the next 5 items are in the executive function domain (e.g., "shifting easily from one activity to the next"), and the final 3 items are in the language domain (e.g., "expressing myself when speaking"). Total CCI-20 scores and domain-specific scores (memory, executive, and language) were calculated by summing the designated items.

https://doi.org/10.1017/S1355617723000620 Published online by Cambridge University Press

Table 1. Neuropsychological tests included in each cognitive domain

Delayed Memory	HVLT-R	Delayed Total Recall
	Logical Memory II (WMS-III)	Delayed Total Recall
Executive Function	WCST-64 Perseverative Responses	Total Number of Responses
	WCST-64 Total Errors	Total Number of Errors
	Trail Making Test Part B	Completion Time
	Letter Fluency (FAS)	Total Number of Words (all 3 trials)
Language	Boston Naming Test	Total Correct Spontaneous Responses
	Animal Fluency	Total Number of Words

Note: HVLT-R = Hopkins Verbal Learning Test – Revised (Brandt, 2001); WMS-III = Wechsler Memory Scale – Third Edition (Wechsler, 1997); WCST-64 = Wisconsin Card Sorting Test-64 Card Version (Kongs et al., 2000); TMT-B = Trail Making Test Part B (Reitan, 1992); COWA = Controlled Oral Word Association Test (Tombaugh et al., 1999); BNT = Boston Naming Test (Goodglass et al., 1983); Animal Fluency Test (Tombaugh et al., 1999).

Neuropsychological measures

The neuropsychological evaluation included a global screener, the Dementia Rating Scale-2 (DRS-2; Jurica et al., 2001) along with neuropsychological measures across multiple cognitive domains. For the present study, we focused on tests of: (1) delayed memory, (2) executive function, and (3) language. Specific tests for each domain are depicted in Table 1. Normed scores for each neurocognitive measure were obtained from test-specific manuals or previously published norms (Heaton et al., 2004) and then converted to *z*-scores. Composite scores were generated by averaging the normed *z*-scores of all tests within each domain.

Mood and motivation measures

All participants received standard self-report measures of depression (Beck Depression Inventory-II (BDI-II; Beck et al., 1996)), anxiety (State-Trait Anxiety Inventory (STAI; Spielberger & Gorsuch, 1983)), and apathy (Apathy Scale (AS; Starkstein et al., 1992)). The BDI-II is a 21-item scale that assesses depressive symptoms over the past two weeks. Total scores range from 0 to 63, with higher scores indicating greater depressive symptoms. The STAI is a 40-item self-report measure divided into "state" (i.e., how an individual currently feels) and "trait" (i.e., how an individual generally feels) subscales. Total scores for each subscale range from 20 to 80, with higher scores indicating greater levels of anxiety. The AS is a 14-item scale that assesses motivational symptoms over the past two weeks. Total scores range from 0 to 42, with higher scores indicating greater apathy symptoms.

Motor severity measures

Motor symptom severity was indexed using disease-specific scales given by movement disorders neurologists. Participants with PD received the Unified Parkinson's Disease Rating Scale motor examination (UPDRS-III; Fahn & Elton, 1987), which ranges from 0 to 108; higher scores indicate greater severity of motor symptoms. Participants with ET received the motor portion (items 1–14) of the Fahn–Tolosa–Marin Clinical Rating Scale for Tremor (TRS; Fahn et al., 1993). Total motor scores range from 0 to 116, with higher scores indicating greater tremor severity.

Statistical analyses

All analyses were conducted in SPSS Version 27 and SPSS AMOS Graphics 26. We performed a series of one-way analyses of variance (ANOVA) to determine differences in demographic, cognitive, mood/motivation, and disease-related variables between PD and ET groups (i.e., age, education, disease duration, DRS-2, neuropsychological domain scores, BDI-II, STAI, AS). Univariate analysis of covariance (ANCOVA) controlling for age and education assessed group differences in CCI-20 total scores.

Confirmatory factor analysis (CFA) was performed on the CCI-20 to determine the fit of a three-cognitive domain structure (memory, executive, and language), as outlined by Rattanabannakit et al. (2016). This model resulted in several unacceptable fit indices, and thus exploratory factor analysis (EFA) was conducted to explore alternative models using promax rotation and factor extraction based on scree plot visual inspection and Kaiser's criterion (eigenvalues > 1.0). Items which demonstrated significant cross-loading on multiple factors or nonsignificant loadings on a single factor were excluded. Item loadings ≥ 0.32 were considered significant (Tabachnick & Fidell, 2007). Cronbach's alpha was used to assess internal consistency reliability. Finally, CFA was conducted on the factor structures revealed by the EFA to determine the best-fitting model.

Multiple fit indices were used to evaluate models' goodness of fit: overall chi-square, Comparative Fit Index (CFI; Hu & Bentler, 1998), Tucker-Lewis Index (TLI; Tucker & Lewis, 1973), root mean square error of approximation (RMSEA; Steiger, 1990), standardized root mean square residual (SRMR), Akaike Information Criteria (AIC), and Bayesian Information Criterion (BIC). The following fit indices determined acceptable fit: SRMR ≤ 0.08; CFI ≥ 0.95; TLI ≥ 0.95; RMSEA ≤ 0.06 (Hu & Bentler, 1998). Lower AIC and BIC values indicated better model fit.

The CCI-20 total and factor scores (i.e., sum of items within each factor) obtained from the best-fitting model were used as outcome variables in separate hierarchical regressions that examined the relationship with neurocognitive domains. Block 1 predictors included composite scores for delayed memory, executive, and language domains. Block 2 included mood predictors for depression (BDI-II), dispositional anxiety (STAI-Trait), and apathy (AS). Demographic factors were not included in this model given that norming procedures of the neuropsychological measures partially accounted for age, education, and sex in various permutations. If neuropsychological composite scores were found to be significant predictors, regressions were repeated using the individual neuropsychological test z-scores that made up that composite as predictors in Block 1 and mood measures (BDI-II, STAI-Trait, AS) were used as predictors in Block 2.

Results

Sample characteristics

Demographic characteristics of the PD ($N = 149$) and ET ($N = 67$) participants and their scores on cognitive, mood, and disease-related measures and the CCI-20 are depicted in Table 2. As shown, the PD participants were younger, slightly more educated and had shorter disease duration than the ET participants. The latter reflects the well-known bimodal distribution of onset age in ET, with some individuals exhibiting symptoms in their teens/early

https://doi.org/10.1017/S1355617723000620 Published online by Cambridge University Press

Table 2. Demographic and clinical characteristics of study sample

	Combined ($n = 216$)	Parkinson's disease ($n = 149$)	Essential tremor ($n = 67$)	p-value
Age	67.7 ± 9.3	65.4 ± 9.3	72.8 ± 7.1	$p < .001$*
Education	15.0 ± 2.9	15.4 ± 2.8	14.1 ± 3.1	$p < .001$*
Gender, female (%)	78 (36.1)	50 (33.6)	28 (41.8)	$p = .24$
Race/Ethnicity, White (%)	205 (94.9)	138 (92.6)	67 (100)	$p = .16$
Black (%)	3 (1.4)	3 (2)	0 (0)	
Hispanic (%)	7 (3.2)	7 (5)	0 (0)	
Other (%)	1 (0.5)	1 (0.7)	0 (0)	
Disease Duration (Years)	12.0 ± 10.6	8.6 ± 4.4	19.4 ± 15.5	$p < .001$*
DRS-2	133.7 ± 8.7	134.2 ± 8.6	132.6 ± 8.8	$p = .19$
BDI-II	9.1 ± 7.9	9.7 ± 7.9	7.8 ± 7.7	$p = .12$
AS	10.9 ± 6.2	11.4 ± 6.0	9.9 ± 6.3	$p = .09$
STAI-State	38.0 ± 10.9	39 ± 11.1	35.9 ± 10.0	$p = .06$
STAI-Trait	34.6 ± 9.9	35.3 ± 10.2	33.2 ± 9.3	$p = .17$
CCI-20 Total	36.5 ± 12.8	37.6 ± 12.7	34.2	$p = .07$
Delayed Memory Z-Score Composite	−.32 ± 1.1	−.35 ± 1.1	−.23 ± 1.0	$p = .19$
Executive function Z-Score Composite	−.58 ± .97	−.56 ± .93	−.62 ± 1.1	$p = .61$
Language Z-Score Composite	−.18 ± 1.2	−.24 ± 1.2	−.04 ± 1.1	$p = .28$
UPDRS-III	–	24.8 ± 12.3	–	–
TRS-motor	–	–	35.9 ± 13.4	–

Note: Values are presented as mean ± standard deviation, other than for the gender and race/ethnicity variables which are presented as *N* (%); *p*-values are provided for differences between Parkinson's disease and essential tremor groups.
DRS-2 = Dementia Rating Scale-2; BDI-II = Beck Depression Inventory-II; AS = Apathy Scale; STAI = State-Trait Anxiety Inventory; UPDRS-III = Unified Parkinson's Disease Rating Scale Part 3; TRS = Fahn-Tolosa-Marin Clinical Rating Scale for Tremor.
*$p < .05$.

Table 3. Comparison of goodness-of-fit indices across models

Model	X^2	df	CFI	TLI	RMSEA (90% CI)	SRMR	AIC	BIC
Rattanabannakit's 3-factor structure	390.864*	167	.909	.896	.079 (.069–.089)	.042	477	486
EFA 3-factor structure	346.397*	167	.927	.917	.071 (.06–.081)	.042	434	578
EFA 2-factor structure[a]	296.0*	134	.924	.913	.075 (.063–.087)	.041	370	495

Df = degrees of freedom; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; SRMR = Standardized Root Mean Square Residual; AIC = Akaike Information Criteria; BIC = Bayesian Information Criterion.
[a]Excluding items 7 and 8.
*$p < 0.01$.

adulthood and others much later (Louis & Dogu, 2007). Otherwise, the PD and ET groups did not differ significantly in their scores across the CCI-20, a dementia screener (DRS-2), any of the neuropsychological domain composites (delayed memory, executive, language), or mood scales. The latter findings correspond to those of Ratajska, Scott, et al. (2022). For this reason, the PD and ET participants were combined into a single group for further analyses. As a single group, participants were well-educated ($m = 15.01 \pm 2.92$), in their mid-60's ($m = 67.72 \pm 9.33$), predominantly male (63%), and non-Hispanic White (93.6%).

Aim 1: Factor analyses of the CCI-20 in movement patients

Aim 1 examined the factor structure of the CCI-20 to determine whether a 3-factor structure (memory, executive, language) aligned with the domains described by Rattanabannakit et al. (2016). The resulting CFA failed to provide a good fit, as indicated by a large and significant chi-square test statistic ($\chi 2$ [167; $N = 216$] = 390.864; $p < 0.001$), CFI (.909) and TLI (.896) values below recommended cutoff, and a RMSEA value slightly above acceptable cutoff (.079, 90% CI = .069–.089). A subsequent EFA was conducted on the CCI-20 items to examine emergent factors. Visual inspection of the scree plot and Kaiser's criterion (eigenvalues > 1) suggested a two-factor and three-factor structure, respectively. The three-factor structure from the EFA differed, however, from the original domains proposed by Rattanabannakit et al. (2016); factor one included eight of the twelve memory items (items 1–4, 6, 10–12), factor two included all executive and language items (items 13–20), and factor three included the remaining four memory items (items 5, 7–9). All items loaded onto at least one factor in both the two- and three-factor models; however, items seven and eight in the two-factor model demonstrated significant cross-loading on both factors. As such, these two items were excluded, and CFAs were run on the 18-item two-factor structure and the 20-item three-factor structure to assess model fit.

Table 3 depicts goodness-of-fit comparisons for the two- and three-factor models. As shown, fit indices revealed that the two-factor structure had slightly better fit. Specifically, almost all fit indices for the two-factor structure were close to acceptable ranges ($\chi 2$[134; $N = 216$] = 296.0; $p < 0.001$; SRMR = .041, CFI = .924, TLI = .913, RMSEA = .075 [90% CI = .063–.087]) and had lower (better) comparative fit values (AIC = 370, BIC = 495) relative to the three-factor structure ($\chi 2$[167; $N = 216$] = 346.397; $p < 0.001$; SRMR = .042, CFI = .927, TLI = .917, RMSEA = .071, [90% CI = .06–.081], AIC = 434, BIC = 578). However, some fit indices for the two-factor structure were marginally worse than the EFA-derived three-factor structure, such as CFI, TLI, and RMSEA values. Given that the difference between CFI and TLI values were within .01 and RMSEA values were within each other's confidence interval, these fit indices were considered equivalent between the two structures, further supporting the extraction of two factors.

After the exclusion of items seven and eight, the two-factor structure explained 56.7% of the total variance. Factor one

https://doi.org/10.1017/S1355617723000620 Published online by Cambridge University Press

Table 4. Final two-factor solution pattern matrix

Item	Factor 1: Memory	Factor 2: Non-Memory
1. Recalling information when I really try	**0.870**	−0.107
2. Remembering names and faces of new people I meet	**0.776**	−0.174
3. Remembering things that have happened recently	**0.760**	0.035
4. Recalling conversations a few days later	**0.665**	0.114
5. Remembering where things are usually kept	**0.346**	0.293
6. Remembering new information told to me	**0.613**	0.113
9. Remembering names of family members and friends	0.072	**0.428**
10. Remembering without notes and reminders	**0.562**	0.091
11. People who know me would find that my memory is	**0.706**	0.092
12. Remembering things compared to my age group	**0.595**	0.211
13. Making decisions about everyday matters	0.162	**0.609**
14. Reasoning through a complicated problem	0.310	**0.488**
15. Focusing on goals and carrying out a plan	0.271	**0.600**
16. Shifting easily from one activity to the next	0.080	**0.574**
17. Organizing my daily activities	−0.069	**0.845**
18. Understanding conversations	−0.074	**0.823**
19. Expressing myself when speaking	0.009	**0.670**
20. Following a story in a book, movie or TV	−0.112	**0.771**
Eigenvalues	8.830	1.382
% of variance	49.058	7.679

Significant factors are indicated in bold.

Table 5. Hierarchical regression of total cognitive complaints

Dependent variable: Total cognitive complaints	*F* change	R^2 change	Beta	Sig
PD + ET				
Block 1: Cognition	2.158	0.033		0.094
Delayed memory			−0.082	0.337
Executive function			−0.141	0.101
Language			0.024	0.777
Block 2: Mood/motivation	26.126	0.289		<0.001*
Delayed memory			0.019	0.258
Executive function			−0.086	0.241
Language			0.000	0.995
BDI-II			0.317	0.002*
STAI-Trait			0.122	0.146
AS			0.160	0.044*
PD only				
Block 1: Cognition	1.580	0.036		0.197
Delayed memory			−0.067	0.533
Executive function			−0.134	0.194
Language			−0.023	0.818
Block 2: Mood/motivation	18.835	0.300		<0.001*
Delayed memory			0.037	0.686
Executive function			−0.062	0.474
Language			−0.033	0.692
BDI-II			0.314	0.011*
STAI-Trait			0.115	0.330
AS			0.216	0.023*
ET only				
Block 1: Cognition	0.773	0.040		0.514
Delayed memory			−0.048	0.746
Executive function			−0.223	0.175
Language			0.174	0.308
Block 2: Mood/motivation	5.984	0.246		<0.001*
Delayed memory			0.011	0.934
Executive function			−0.182	0.234
Language			0.132	0.386
BDI-II			0.374	0.073
STAI-Trait			0.167	0.315
AS			−0.001	0.993

*$p < .05$.

contributed 49.1% of variance and factor two contributed an additional 7.7% of the variance. All memory items (items 1–6, 10–12) except one loaded on factor one and all executive function and language items (items 13–20) and the remaining memory item (item 9) loaded on factor two. See Table 4 for the final pattern matrix. Given the near perfect separation of memory vs non-memory items, factor one was interpreted as representing memory complaints and factor two as representing non-memory complaints. The internal consistency of the 18-item CCI was 0.94, which was the same as the 20-item CCI. The memory complaints factor ($\alpha = 0.91$) and the non-memory complaints factor ($\alpha = 0.90$) both exhibited good internal consistency.

Aim 2: Correspondence between CCI-20 and objective performance on neurocognitive and mood/motivation measures

Aim 2 examined the relationship between SCCs (CCI-20) and objective performance on neurocognitive and mood/motivation measures in the combined PD and ET group. This was tested by conducting three separate hierarchical regressions in the combined sample and then in the PD and ET groups separately. The following dependent variables were used as outcome measures: (1) Total cognitive complaints (DV = CCI-20 total score = sum of items 1–6 and 9–20); (2) memory complaints (DV = sum of items 1–6, 10–12) as derived from the results of the two-factor EFA; and (3) non-memory complaints (DV = sum of items 9, 13–20) as derived from the results of the two-factor EFA. The results of these regressions are shown in Tables 5–7. Block 1 predictors represent performance on neurocognitive measures, while Block 2 predictors represent mood and motivation symptoms.

Total cognitive complaints

As shown in Table 5, the overall model for total cognitive complaints in the combined PD + ET group was significant [$F(6,184) = 14.58$, $p < 0.001$], explaining 32.2% of the variance. The first block was not significant on its own, indicating that objective cognitive performance did not significantly contribute to total SCCs. The second block was significant, with mood/motivation symptoms explaining approximately 28.9% additional variance ($p < 0.001$). Increased symptoms of apathy ($\beta = 0.160$, $p = 0.044$) and depression ($\beta = 0.317$, $p = 0.002$) were associated with greater total SCCs. Similar results were observed when the PD and ET groups were examined separately (PD: [$F(6,125) = 10.54$, $p < 0.001$], 33.6% of variance; ET: [$F(6,52) = 3.48$, $p = 0.006$], 28.6% of the variance). Only Block 2 (mood/motivation symptoms) was significant for each group separately, explaining 30% additional variance in the PD group and 24.6% additional variance in the ET group. For the PD patients, greater apathy ($\beta = 0.216$, $p = 0.023$) and depressive ($\beta = 0.314$, $p = 0.011$) symptoms were associated with greater total cognitive complaints. For ET patients, there were no specific mood predictors of total cognitive complaints.

https://doi.org/10.1017/S1355617723000620 Published online by Cambridge University Press

Table 6. Hierarchical regression of memory complaints

Dependent variable: Memory complaints	*F* change	R^2 change	Beta	Sig
PD + ET				
Block 1: Cognition	1.205	0.019		0.309
Delayed memory			−0.099	0.247
Executive function			−0.079	0.359
Language			0.039	0.463
Block 2: Mood/motivation	20.817	0.249		<0.001*
Delayed memory			−0.013	0.861
Executive function			−0.035	0.642
Language			0.012	0.867
BDI-II			0.367	<0.001*
STAI-Trait			0.039	0.688
AS			0.154	0.063
PD only				
Block 1: Cognition	0.951	0.022		0.418
Delayed memory			−0.074	0.491
Executive function			−0.087	0.399
Language			−0.014	0.891
Block 2: Mood/motivation	14.454	0.252		<0.001*
Delayed memory			−0.013	0.861
Executive function			−0.035	0.642
Language			0.012	0.867
BDI-II			0.352	0.006*
STAI-Trait			0.005	0.969
AS			0.217	0.029*
ET only				
Block 1: Cognition	0.521	0.028		0.670
Delayed memory			−0.086	0.565
Executive function			−0.134	0.433
Language			0.192	0.263
Block 2: Mood/motivation	5.517	0.235		0.002*
Delayed memory			−0.013	0.861
Executive function			−0.035	0.642
Language			0.012	0.867
BDI-II			0.465	0.029*
STAI-Trait			0.068	0.686
AS			−0.038	0.822

*$p < .05$.

Table 7. Hierarchical regression of non-memory complaints

Dependent variable: Non-memory complaints	*F* change	R^2 change	Beta	Sig
PD + ET				
Block 1: Cognition	4.617	0.069		0.004*
Delayed memory			−0.030	0.718
Executive function			−0.241	0.005*
Language			−0.012	0.880
Block 2: Mood/motivation	27.360	0.287		<0.001*
Delayed memory			0.081	0.257
Executive function			−0.173	0.016*
Language			−0.027	0.700
BDI-II			0.153	0.124
STAI-Trait			0.336	<0.001*
AS			0.142	0.066
PD only				
Block 1: Cognition	2.769	0.061		0.044*
Delayed memory			−0.039	0.711
Executive function			−0.206	0.044*
Language			−0.038	0.700
Block 2: Mood/motivation	21.794	0.322		<0.001*
Delayed memory			0.087	0.327
Executive function			−0.124	0.141
Language			−0.045	0.576
BDI-II			0.178	0.128
STAI-Trait			0.323	0.005*
AS			0.176	0.054
ET only				
Block 1: Cognition	1.993	0.098		0.126
Delayed memory			0.039	0.784
Executive function			−0.372	0.027*
Language			0.095	0.565
Block 2: Mood/motivation	4.551	0.188		0.007*
Delayed memory			0.081	0.538
Executive function			−0.315	0.042*
Language			0.077	0.611
BDI-II			0.101	0.624
STAI-Trait			0.324	0.055
AS			0.071	0.666

*$p < .05$.

Memory complaints

The overall model for subjective memory complaints in the combined PD + ET group was significant [$F(6,184) = 11.20$, $p < 0.001$] and explained 26.8% of the variance (see Table 6). Block 2, but not Block 1, was significant, with mood/motivation symptoms accounting for 24.9% of the variance ($p < 0.001$). Increased symptoms of depression ($\beta = 0.367$, $p < 0.001$) were associated with greater memory complaints. Similar results were obtained in the PD only [$F(6,125) = 7.85$, $p < 0.001$] and ET only group [$F(6,52) = 3.08$, $p = 0.012$], explaining 27.4% and 26.3% of the variance, respectively. Block 2 (mood/motivation symptoms) was significant in both the PD only and ET only groups and accounted for 25.2% and 23.5% additional variance in PD and ET, respectively. Increased symptoms of apathy ($\beta = 0.217$, $p = 0.029$) and depression ($\beta = 0.352$, $p = 0.006$) were associated with greater memory complaints in PD, but only increased symptoms of depression ($\beta = 0.465$, $p = 0.029$) were associated with greater memory complaints in ET.

Non-memory complaints

Finally, the overall model for non-memory complaints (i.e., executive, language) in the combined group was significant [$F(6,184) = 16.97$, $p < 0.001$] and explained 35.6% of the variance (See Table 7). Block 1 (objective cognitive performance) was significant [$F(3,187) = 4.617$, $p = 0.004$] and accounted for 6.9% of the variance. Block 2 (mood/motivation symptoms) was also significant ($p < 0.001$) and accounted for an additional 28.7% of the variance. Increased symptoms of dispositional anxiety ($\beta = 0.336$, $p < 0.001$) and worse performance in the executive domain ($\beta = -0.173$, $p = 0.016$) were associated with greater non-memory complaints.

For each group separately, the overall models for non-memory complaints were significant (PD only: [$F(6,125) = 12.96$, $p < 0.001$]; ET only: [$F(6,52) = 3.47$, $p = 0.006$]) and explained 38.3% and 28.6% of the variance, respectively. In PD, both Block 1 ($p = 0.044$) and Block 2 ($p < 0.001$) were significant and accounted for 6.1% and 32.2% of the respective variance. While executive function was significant in Block 1 ($\beta = -.206$, $p = .044$), it was no longer significant in Block 2. After the addition of Block 2, increased symptoms of dispositional anxiety ($\beta = 0.323$, $p = 0.005$) were associated with greater non-memory complaints. In ET, however, only Block 2 was significant ($p = 0.007$), with mood/motivation symptoms accounting for an additional 18.8% of the variance. Worse performance on executive measures was associated with greater non-memory complaints in ET only ($\beta = -0.32$, $p = .042$). When exploring the contribution of individual executive function tests on non-memory complaints, we found worse performance on the Wisconsin Card Sorting Test (WCST) perseverative responses was associated with greater non-memory complaints in the ET only group ($\beta = -2.2$, $p = .006$), but not in the PD only or combined PD and ET group.

https://doi.org/10.1017/S1355617723000620 Published online by Cambridge University Press

Discussion

The current study had two major findings. First, the original conceptualization of the CCI-20 as reflecting three distinct domains (memory, executive, language) was not supported in a movement disorders sample when it was psychometrically evaluated using a CFA. Instead, we found, based on EFA fit indices, that a two-factor model was a better fit psychometrically and theoretically. The first factor included only memory items from the CCI-20, whereas the second factor included all the non-memory items (executive, language) and one memory item. Both EFA factors demonstrated excellent internal consistency, suggesting the CCI-20 may be an adequate measure of SCCs in persons with PD or ET. To our knowledge, this is the first study to examine the factor structure of the CCI-20 in any population.

There are at least two possible reasons why the obtained two-factor structure in the current study differs from proposed conceptual domains of the CCI-20. First, the items assigned to the memory, executive, and language domains of the CCI-20 were *rationally selected* based on targeted content but never empirically validated via factor analysis in an older adult sample. A second possibility pertains to the fact that our targeted participants were older adults with movement disorders, whereas the initial studies with the CCI-20 were older adults with normal cognition, MCI, and dementia (Saykin et al., 2006; Rattanabannakit et al., 2016). It is unclear why diagnostic group would be important.

Two items from the CCI-20 (i.e., items 7 and 8) were excluded in the current study due to significant cross-loading on both factors. One explanation for the cross-loading relates to the multidomain structure of these questions. Item seven – "remembering where I placed familiar objects" – pertains to spatial memory and item eight – "remembering what I intended to do" – pertains to prospective memory. Item nine, "remembering names of family members and friends" was the only memory item to load onto the non-memory factor. Two competing hypotheses might explain this: (1) item nine differs from the other memory items in that it asks information about remote, overlearned and perhaps 'semantic' information, thereby distinguishing it from traditional episodic memory items, or (2) the semantic component of the question renders it more closely associated with language than memory.

The second major finding of the current study is that the total score and the factor-derived memory domain of the CCI-20 were predominately related to mood/motivation symptoms (i.e., apathy and depression in PD and depression in ET), and not objective neuropsychological measures. Only the factor-derived non-memory domain was linked to objective cognitive performance, namely executive function, and this was primarily observed in individuals with ET. A similar relationship with executive function was also observed in PD, but after accounting for mood/motivational symptoms, the factor-derived non-memory domain was better explained by anxiety and to a lesser extent, apathy. The CCI-20's ability to identify subtle executive deficits may relate to the fact that the executive domain was objectively the lowest (i.e., lowest z-score composite), corresponding to observations that weaknesses/impairment in executive function tasks are among the most common cognitive sequelae in PD and ET cohorts. While studies on SCCs in ET are extremely limited, our findings align with those of Azar and colleagues (2017), who demonstrated that cognitively unimpaired ET individuals accurately perceive their executive function abilities. Prior studies in PD, however, have failed to identify a direct relationship between subjective and objective measures of executive function (Koerts et al., 2011, 2012; Lanni et al., 2014; Vlagsma et al., 2017), consistent with our results. Yet, other studies in PD linking total cognitive complaints with performance across multiple domains have been reported (Koster et al., 2015; Nakhla et al., 2021).

Further exploration into the contribution of individual executive function tests on the factor-derived non-memory domain revealed that more perseverative responses on the WCST-64 were associated with greater non-memory complaints in the ET only group. While this finding should be interpreted with caution due to the nature of the ET only group (i.e., relatively small sample size, greater variability in the data for WCST-64 perseverative responses compared to PD only group), it may also signify that ET individuals who endorse non-memory complaints on the CCI have more trouble with cognitive flexibility than those who do not. Future studies should consider validating this finding in larger ET samples.

Taken together, we found that mood/motivational symptoms were strongly associated with SCCs, both overall and domain specific. In fact, in the regression models we conducted, mood symptoms explained the majority of variance associated with cognitive complaints. There are two important points to consider. One relates to methods variance, namely that the stronger relationship between mood symptoms and cognitive complaints may be due to both being self-report measures rather than performance measures (e.g., neuropsychological tasks; Brannick et al., 2010). Second, it is faulty to interpret the mood-cognitive complaints relationship as causal, specifically that cognitive complaints are solely due to anxiety, depression, and/or apathy. In fact, *subtle* changes in cognition may be co-occurring along with mood changes due to alterations in distinct though overlapping neural systems that worsen with disease severity. Longitudinal studies could more easily address the nature of this relationship. Indeed, Jones and colleagues (2023), using a large sample of newly diagnosed PD patients, found that those with SCCs had greater cognitive decline and increased biomarker abnormalities over a 5-year period compared to PD individuals without SCCs and controls. Purri and colleagues (2020) identified a similar cognitive trajectory in PD-SCC individuals over 2 years. Despite this, neither included longitudinal assessment of mood/motivation symptoms. At least in PD, we know that both cognitive symptoms worsen over time (Aarsland et al., 2021) as do neuropsychiatric symptoms (Weintraub et al., 2020), highlighting the need for future studies to assess *both* neuropsychological and neuropsychiatric functioning across multiple timepoints.

Consistent with previous cross-sectional studies (Miller et al., 2007; Ratajska, Scott, et al., 2022), PD and ET participants scored similarly across mood/motivation measures. Elevated mood symptoms are frequent in PD and ET but appear to affect components of cognition differently (Ratajska, Scott, et al., 2022). Namely, in PD, more severe apathy relates to worse executive function and increased anxiety corresponds to worse attention/working memory (Ratajska, Scott, et al., 2022). In contrast, mood symptoms in ET affect cognitive performance more broadly. Differences in this complex interaction may explain, at least in part, why mood/motivational symptoms appear to play a more prominent role in moderating the relationship between SCCs and objective cognition in those with PD compared to ET. Nonetheless, our study is among several others which link SCCs to increased neuropsychiatric symptoms in patients with movement disorders (Barbosa et al., 2019; Chua et al., 2021; Ophey et al., 2022). Given current findings linking depression/apathy symptoms to memory

https://doi.org/10.1017/S1355617723000620 Published online by Cambridge University Press

complaints and anxiety/apathy symptoms to non-memory complaints, alongside evidence that movement populations report SCCs across multiple domains (Koster et al., 2015; Lanni et al., 2014), future studies should examine the differential relationship between mood symptoms and domain-specific cognitive complaints to better understand whether certain combinations of SCCs and neuropsychiatric symptoms pose an increased risk for future cognitive decline.

The current study utilized an existing multidomain scale, the CCI-20, to quantify SCCs in a movement disorders sample. Use of the CCI-20 in PD and ET has a variety of advantages and disadvantages. One advantage relates to current findings suggesting the CCI-20 is a valid and reliable measure of SCCs and can detect subtle deficits in executive function. Furthermore, the CCI-20 measures SCCs in domains other than memory, which is more appropriate given those with movement disorders show cognitive deficits across multiple cognitive domains (Kenney et al., 2021; Koster et al., 2015; Ratajska, Lopez, et al., 2022). The CCI-20 has also been validated in a cognitively diverse sample of older adults and shown to be correlated to objective tests in the same cognitive domain (Rattanabannakit et al., 2016). Finally, validation of a single measure (i.e., CCI-20) across multiple groups allows researchers to compare response patterns across different clinical populations.

Regarding disadvantages, one primary concern is the CCI-20's susceptibility to mood and motivational influences, necessitating the inclusion of assessments for depression, anxiety, and apathy to account for possible confounds. Additionally, there is no evidence to suggest a comprehensive, multidomain measure of SCCs is superior to a single yes/no question; in fact, some studies have found a single question about the presence of SCCs to be predictive of future cognitive decline in PD (Jones et al., 2023; Purri et al., 2020). Finally, informant-reported SCCs may be more accurate than self-reported SCCs if there is suspicion of underlying cognitive impairment, given concern for underreporting in patients with cognitive dysfunction (Azar et al., 2017; Copeland et al., 2016). Given the dramatic heterogeneity in the cognitive profiles and long-term trajectories of persons with movement disorders, we recommend using a multidomain scale with broader cognitive domain assessment (i.e., memory, executive, language, attention, and visuospatial) such as the Everyday Cognition Scale (ECog; Farias et al., 2008), which has demonstrated good internal consistency and reliability in PD (Koster et al., 2015). Conversely, in situations where time and efficiency are paramount, such as clinical settings, a single yes/no question may be sufficient.

Regarding implementation of the 18-item vs. 20-item CCI in PD and ET populations, we recommend use of the 18-item CCI for research purposes, especially if investigators are interested in examining differential factors related to memory vs. non-memory cognitive complaints. This relates to the fact that items seven and eight were observed to significantly cross-load onto two factors, and thus it remains unclear whether they are truly representative of memory complaints, non-memory complaints, or both. For clinical purposes, we recommend the administration of the CCI-20, given the exclusion of items seven and eight did not improve the CCI's internal consistency, and retention of these items may provide other potentially valuable information about spatial and prospective memory. Clinicians interested in using the CCI-20 for research purposes can choose to exclude these items later.

Our study had several limitations. First, data were obtained from a cross-sectional sample of PD and ET patients being seen at a tertiary movement disorder center. Follow-up longitudinal studies with a wider range of patient characteristics, such as inclusion of individuals from marginalized backgrounds, other geographic locations, and fewer years of education, are needed to achieve generalizable findings. Second, individuals in our sample were being seen as part of an interdisciplinary workup to determine candidacy for DBS surgery. Given the nature of the evaluation, these individuals may be incentivized to under-report cognitive complaints to increase their chances of receiving the surgery. As such, cognitive complaints in this setting may not reflect their prevalence in a large community-based population. Finally, the current study did not examine differences in SCCs between cognitively intact and impaired individuals, despite evidence to suggest awareness decreases with cognitive impairment and transition to MCI (Azar et al., 2017; Copeland et al., 2016; Pennington et al., 2021).

In conclusion, the current study adds to literature in two ways. First, we identified two distinct dimensions of SCCs in patients with PD or ET: memory and non-memory complaints. Of the cognitive domains assessed, executive function was the only domain to correspond to SCCs. Namely, subtle deficits on executive measures were associated with increased non-memory complaints on the CCI-20. Second, above and beyond cognition, increased mood/motivational symptoms were a primary driver of all dimensions of SCCs. Taken together, greater non-memory complaints on the CCI-20 may be indicative of executive dysfunction in PD and ET patients; however, underlying mood/motivational disturbance should be addressed to rule out possible confounds. Overall, the current study provides preliminary evidence for the psychometric adequacy of the CCI-20 in a movement disorders sample. Future work should consider a longitudinal approach to understand the clinical evolution and prognostic value of SCCs in these populations.

Funding statement. Funding was provided by the National Institute of Health (J.L. & J.B., T32 AG061892), (D.B. & D.V., T32 NS082168), (D.B., R01 AG064587) and UF Norman Fixel Institute.

Competing interests. The authors declare that there are no conflicts of interest relevant to this work.

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