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Factor structure of the Montreal Cognitive Assessment items in a sample with early Parkinson's disease

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ABSTRACT

Introduction: The Montreal Cognitive Assessment (MoCA) is a frequently utilized cognitive screening tool that has attractive clinical attributes when utilized in individuals with Parkinson's disease. However, the construct validity of this instrument has not been well-characterized in Parkinson's samples. The purpose of this study is to explore the underlying factor structure of the MoCA in individuals with early stage Parkinson's disease.

Method: Item responses from the MoCA in 357 individuals with Parkinson's disease from the Parkinson's Progression Markers Initiative were analyzed first for frequency of errors and polychoric inter item correlations. This correlation matrix was then analyzed with exploratory factor analysis.

Results: Omitting items with ceiling effects, three factors emerged which explained the majority of the variance. These factors were reflective of executive dysfunction, memory, and verbal attention. Scores on the MoCA and all of its subscales were significantly different between individuals with Parkinson's disease-no cognitive impairment and those who met criteria for mild cognitive impairment.

Conclusions: In keeping with prior studies in Parkinson's disease, executive dysfunction seems to underpin performance of many items of the MoCA. Implications of this finding both in terms of optimizing the MoCA for use in this population and further steps to validate the constructs behind the MoCA are discussed.

1. Introduction

Parkinson's disease (PD) is more than a disorder of movement. Even in the absence of PD related mild cognitive impairment (MCI) or dementia, a review of recent population based studies revealed that as many as 30% of newly diagnosed Parkinson's patients may demonstrate cognitive deficits even very early in the disease course [1,2].

While many screening instruments for Parkinson's disease cognitive decline have been developed, the Montreal Cognitive Assessment (MoCA) has a number of attractive qualities for use in this population. The MoCA has been demonstrated to be more sensitive to cognitive deficits in Parkinson's disease than other screening measures such as the mini mental state examination, discriminates well between individuals with PD related cognitive impairment and those without, and demonstrates good test – retest reliability at the total score level [3–5]. Indeed, given the MoCA's utility at discriminating between individuals with MCI and dementia, has been described as a "well suited screen for cognitive impairment in Parkinson's disease" [6], though this contention has been disputed by other authors [7].

While the instrument as a whole has attractive clinical utility, other important psychometric properties, such as construct validity, have not been well explored in those with PD. Construct validity is defined as "the extent to which the test may be said to measure a theoretical construct or trait" [8] and is necessarily the product of a process rather than a single study. There are many

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methods of assessing construct validity, but factor analysis is one step. When initially designed, the MoCA was intended to capture several cognitive domains, including executive functions, memory, language, attention, orientation, and visuospatial abilities [9]. Given that Parkinson's disease can impact many cognitive functions, a multi-domain screening instrument is an attractive proposition. In fact, in recommending the MoCA as a cognitive screening tool for Parkinson's disease, a Movement Disorder's Task Force identified the breadth of cognitive domains screened for by the MoCA as one of its strengths [10]. While on its face the instrument does screen a variety of domains, whether these factors actually emerge as independent cognitive constructs in PD has yet to be established.

There is some empirical support to the notion that the MoCA may represent six relatively separable cognitive factors in normal populations. Freitas and colleagues (2012) evaluated the factor structure of the MoCA in a large normative sample of Portuguese-speaking older adults and a mixed clinical sample [11]. Results revealed a good fit to a traditional six-factor model underlying the instrument. However, similar analyses in other samples have not supported this finding. In a mixed neurodegenerative sample that included standard neuropsychological instruments, MoCA subscales generally loaded onto four as opposed to six factors [12]. It is notable, though, that many items showed strong cross loadings, particularly among working memory/attentional and executive domains, two aspects of cognitive functioning that are central to neuropsychological assessment in individuals with PD. Also, Coen and colleagues found poor fit indices with traditional six-factor models, with exploratory analyses revealing a three-factor model—a model that was difficult to interpret given cross loading among items [13]. Thus, in the early development of this promising instrument, the structure underlying the measure, especially in clinical samples, warrants further investigation.

To date, there have not been factor analytic studies of the MoCA in PD (to our knowledge). However, multiple item level analyses have been published recently that raise concern about the relative utility of individual items in PD samples. For example, Roalf and colleagues utilized item response theory analysis MoCA items in a mixed sample of individuals with neurodegenerative disorders, which included 781 individuals with Parkinson's disease to identify the most informative items from the instrument. Only eight items (clock drawing, serial subtractions, orientation, recall, $^{1}/_{3}$ of the naming items, ½ of the abstraction items, trailmaking, and phonemic fluency) provided significant statistical information [14]. In fact, utilizing these items alone provided similar diagnostic classification accuracy to the instrument as a whole. Similarly, Fengler and colleagues found that revising the scoring system of the MoCA to differentially weight certain executive functioning items and memory items improved the discriminability of the measure [15]. These authors concluded that language and orientation items were not as informative—with the exception of sentence repetition, which may have been due to the attentional rather than language demands of the task.

From a theoretical standpoint, it's important to recognize that factor structures derived from samples without neurological disease may not generalize to neurologically compromised samples [16]; for example, executive dysfunction is pervasive in Parkinson's disease—therefore, it's possible that items on a myriad of sub scales from the MoCA could be linked via a common executive component. Clock drawing is one item that is conceptualized as a visual task on the MoCA, but it is recommended to be interpreted as an executive measure in Parkinson's disease [1]. The notion of an attention/working memory/concentration domain (distinct from executive functioning) is also potentially problematic as most modern models of attention/working memory represent a complex multi-component attentional structure that overlaps with executive control systems [17]. Thus, understanding cognitive factors in particular patient populations, such as Parkinson's disease, is critical to understanding the constructs represented by neuropsychological instruments [16].

To this end, the current study sought to explore the construct validity of the MoCA in an early Parkinson's disease sample. Specifically, we evaluated item level responses to identify rarely missed items. We next evaluated inter-item correlations among informative items and performed a factor analysis study to identify possible underlying cognitive domains within the sample. Finally, we explored differences of these possible factors between individuals with PD-MCI and normal cognition to see if there was a particular pattern of weaknesses seen in PD-MCI on the MoCA relative to individuals with normal cognition.

2. Method

2.1. Participants

Data from the current study came from the Parkinson's Progression Markers initiative (PPMI); more information, including the study's methods, policies, and procedures, is freely available online at www.pmmi-info.org. While the PPMI recruited many cohorts, the focus of this study was the group of individuals with de novo diagnoses of Parkinson's disease. All procedures and processes are overviewed by the local IRB committees of the study sites, and research was completed in accordance with the Helsinki Declaration.

To be included in the PD cohort study at baseline, individuals must have motor manifestations of Parkinson's disease, have been diagnosed for less than two years at their screening visit, have relatively limited disability at baseline, and have confirmatory evidence of dopamine transporter deficit on imaging. Participants were excluded from the study if they were taking Parkinson's disease medications at the beginning of the study, or had known or suspected other health conditions that could be causing their Parkinsonism or interfere with study related activities.

From a cognitive standpoint, patients are assessed with the MoCA during their screening assessment and then receive the MoCA in addition to a brief neuropsychological battery described below at yearly visits. Baseline data from the MoCA were published recently [18]. At the cognitive baseline, abnormal MoCA scores were relatively rare, with only 22% of individuals scoring less than or equal to 26. When we analyzed individual items at baseline, multiple perfect correlations were observed between items because of the limited variability in responses. A similar pattern was observed at the 24-month visits. Because of the restricted range of variability with this baseline data, we decided to utilize the evaluations performed at 36 months post-baseline (during the eighth visit) to increase variability for the psychometric study. Individuals were included from the PD cohort with completed MoCAs ($n = 357$).

2.2. Cognitive assessment and other clinical assessments

In addition to the MoCA, participants were yearly administered an abbreviated neuropsychological battery [18]. Site investigators reviewed neuropsychological and other clinical data at each visit after the baseline to categorize participants as having normal cognitive status, MCI, or dementia. Of note, the MCI diagnosis is determined separate from the MoCA score. Participant motor features were characterized by the Unified Parkinson's Disease Rating Scale (III. Motor Examination) [19].

2.3. Statistical analysis

Statistical analyses were performed using Stata version 13.0. We first evaluated the frequency of errors on the individual items of the MoCA. Due to our focus on the individual items, the point awarded for educational attainment (usually total scores are increased by one point for education less than or equal to high school) are not included in the analyses or reporting of the MoCA scores. While most items were coded as dichotomous variables, serial 7 subtractions (scores range from 0 to 3), sentence repetition, and verbal abstraction items (both 0–2) were coded polytomously. Given the infrequent nature of errors on some of the dichotomous items, we screened for singularity amongst items by first examining tetrachoric correlations to identify near-perfect relationships among items which would be omitted from further analysis. As a result of the mix of dichotomous and polytomous data types, we then utilized the Polychoric user generated command in Stata [20] to evaluate the polychoric correlation matrix amongst the items. We subsequently performed exploratory factor analysis on this matrix. Given the lack of consensus in the literature as to the underlying factor structure of the MoCA in Parkinson's disease, exploratory (rather than confirmatory) analyses were performed. After identifying the underlying factor structure, we explored the difference in these subscales in the group of individuals with Parkinson's disease without cognitive impairment and those with PD-MCI.

3. Results

The mean age of the sample was 63.99 ($SD = 9.77$), 65% were male, and most had at least some college education (years of education $M = 15.59$, SD=2.93). Mean Unified Parkinson's Rating Scale score was 28.38 ($SD = 12.14$). Cognitively, average total MoCA score was 26.37 ($SD = 3.08$), with 75% of the sample having no cognitive diagnoses, 21% diagnosed with mild cognitive impairment, and 1.4% carrying a diagnosis of dementia.

The percentage of correct responses for individual items from the MoCA is presented in Table 1. Several items were noted to be rarely missed (operationalized as less than 95% correct). The three naming items, all of the orientation items except for day of the month and the forward digit span, were all identified as nearly universally correct in this sample. Because the orientation and naming items were conceptually similar and rarely missed as a group, they were excluded from further analysis. Similarly, forward digit span and the vigilance/tapping item showed extremely limited variability. When we examined tetrachoric correlations amongst the dichotomous items, singularity (1.0) correlations tended to occur among these remaining rarely missed variables. The decision was made to omit the vigilance task for this analysis to avoid this confound.

The polychoric correlation matrix was subsequently submitted to exploratory factor analysis, with 3 factors emerging with Eigenvalues greater than 1 and explaining 39.4, 16.5, and 10.8% of the variance, respectively. Given the likelihood of interrelationships amongst the factors, an oblique rotation (Promax) was utilized to better interpret the data. Table 2 presents the item factor loadings of individual items in the final rotated solution.

The first factor, which loaded verbal fluency, clock drawing, cube copy, backward digit span, and serial 7 subtractions, was labeled as an “executive function” factor. A clearly defined “memory” factor consisted of the memory items. The third factor was termed a “verbal attention factor”, which included a cross loading of serial 7 subtractions (from the executive scale) as well as forward digit span and sentence repetition.

In clinical practice, it is easier to evaluate subscales created from the sum of raw items rather than factor scores. To this end, we compared group level differences between those diagnosed with PD-MCI and those with PD-no cognitive impairment on each of the subscales and the (non-education corrected) MoCA as a whole. Given unequal sample sizes and skewed distributions, we utilized non-parametic Wilcoxon rank sum tests. Results revealed significant differences between the groups on all subscales (executive $I = 4.84$, $p < 0.0001$; memory $Z = 5.41$, $p < 0001$; attention $Z = 2.64$, $p < 0.01$), as well as the instrument as a whole ($Z = 7.05$, $p < 0.0001$), although median scores were similar in between the groups.

4. Discussion

The validation of a cognitive instrument such as the MoCA is a continuous process, requiring a variety of approaches, including construct validation. To this end, the current study demonstrates some unique features of the MoCA in early Parkinson's disease. Notably, in this early PD sample as well in other neurological populations described in the introduction, several of the items from the MoCA are rarely missed. Confrontation naming, digits forward, and orientation items in particular were correct in over 95% of these individuals with early Parkinson's disease. The ceiling effects of these items do not necessarily suggest the instrument has a weakness; nor would ceiling effects on a naming screen be unexpected in Parkinson's disease, where confrontation naming of nouns and orientation are not usually impaired so early in the course of the disease [2]. However, these items are problematic psychometrically and insensitive to core cognitive difficulties in Parkinson's disease. Thus, for clinicians and researchers working on developing short form screening instruments or hoping to capture more subtle language difficulties, modifications or omissions of these items would likely prove fruitful.

Our current results suggest an underlying three-factor structure of the MoCA, as was previously suggested by Coen and colleague's analysis (2015), though item loadings were different in our sample [13]. The factor that explained the majority of the variance in the current study was a group of items we believe reflects executive functioning. While executive function as a construct has been criticized given the variety of cognitive constructs subsumed by this term [21,22], the current study demonstrated that items as disparate as clock drawing, cube copy, and verbal fluency all share some underlying variance in this Parkinson's disease sample. This is not surprising given that clock drawing [23], phonemic verbal fluency [24], and number/letter alternation [25] are frequently found to be impaired in individuals with frontal lobe dysfunction, which is typically thought to be a critical (though not isolated) neuroanatomical substrate of executive dysfunction. Thus, our results in a sample of Parkinson's disease—which is defined by fronto-subcortical network dysfunction—once again support the idea of a similar underlying factor driving performance on these tasks. That several attention and working memory items, such as serial 7 subtractions and digits backwards [26], also share variance with this executive construct is not surprising given executive control of working memory is frequently recognized in modern accounts of working memory [17]. Finally, top down (or executive control) of visual attention—in addition to more posterior cortical systems—are associated with constructional praxis in neurodegenerative disorders [27], and thus distortions on cube copy may reflect underlying executive functioning. So, whereas the MoCA was originally designed to tap six factors of cognition, many of the items can actually be influenced by executive dysfunction, and care should be taken when interpreting items as markers of some other construct in groups at risk for underlying fronto-subcortical disruption. A similar pattern was seen on the attention factor, where a “language” task in sentence-repetition loaded together

Table 1
Item level performances on the Montreal Cognitive Assessment.

MoCA item		% Correct	Scores for ordinal items
Letter/Number Sequencing		84.59	
Cube		75.35	
Clock-Circle		*98.60*	
Clock- Numbers		88.80	
Clock- Hands		83.75	
Lion		*98.88*	
Rhino		*95.24*	
Camel		*98.88*	
Forward Digit Span		*96.36*	
Backward Digit Span		91.88	
Letter Vigilance		*96.92*	
Serial 7	- 3 points		85.71
	- 2 points		10.36
	- 1 points		2.80
	- 0 points		1.12
Sentences	- 2 points		75.91
	- 1 points		21.57
	- 0 points		2.52
Verbal Fluency		78.15	
Abstraction	- 2 points		88.20
	- 1 points		10.11
	- 0 points		1.69
Word 1 Recall		56.74	
Word 2 Recall		75.56	
Word 3 Recall		67.13	
Word 4 Recall		44.38	
Word 5 Recall		63.48	
Date		*93.26*	
Month		*99.44*	
Year		*99.72*	
Day of the Week		*98.88*	
Place		*98.03*	
City		*100.00*	

Italics indicates rarely missed items.

Table 2
Rotated factor loadings of MoCA items.

Variable	Factor 1	Factor 2	Factor 3	Unique variance
L/N Sequence	**0.47**	0.03	−0.20	0.78
Verbal Fluency	**0.44**	−0.01	0.22	0.72
Abstraction	**0.44**	0.07	0.10	0.75
Digit Backwards	**0.39**	0.14	−0.08	0.80
Serial 7	**0.36**	0.08	**0.43**	0.57
Sentence Repetition	−0.10	0.09	**0.82**	0.33
Cube Copy	**0.69**	−0.04	0.00	0.54
Clock Numbers	**0.72**	−0.06	−0.13	0.54
Cloc Hours	**0.75**	0.04	0.00	0.42
Recall 1	0.11	**0.68**	0.01	0.46
Recall 2	0.26	**0.77**	−0.10	0.23
Recall 3	0.05	**0.85**	0.05	0.22
Recall 4	−0.29	**0.84**	0.20	0.30
Recall 5	−0.01	**0.86**	−0.14	0.30
Clock Circle	**0.78**	0.02	0.16	0.29
Forward Digit Span	0.22	−0.15	**0.72**	0.40

Bolded text indicates factor loading >.35.

with forward digit span and serial 7 subtractions that suggested errors in Parkinson's disease were more attentional in nature rather than reflective of underlying language dysfunction.

Overall, individuals with PD-MCI perform worse on the MoCA as a whole and worse on the identified subscales than those with PD and no cognitive dysfunction. It should be noted that these differences were observed on the subset of items that did not have significant ceiling effects as well as the instrument as a whole. While instrument having ceiling effects on some items in a screening is not necessarily a limitation, the relative frequency of rarely missed items on the MoCA continues to raise the question as to whether the MoCA can be optimized to improve the sensitivity and specificity to cognitive impairment in early PD while minimizing time to administer. This is important when one factors in the relatively poor association between MoCA scores and clinical diagnosis of MCI in baseline PPMI data [18].

Further study is needed regarding the MoCA's psychometric properties in both broad normative samples as well as more specific neurological samples. The factorial invariance of the measure both in a more cognitively impaired/advanced Parkinson's disease sample as well as other clinical samples is needed to help aide clinic and research use of the instrument. As exploratory factor analysis is open to interpretation, future studies could build on the current by using confirmatory factor analysis to help clarify the cognitive structure. Exploring the convergent and divergent validity of the subscales with other well-validated neuropsychological instruments is also encouraged. Finally, exploring this sample in samples reflecting broader cultural, linguistic, and socio-economic diversity is critical for clinical application of this instrument in broader patient populations.

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