Fine tuning cognitive assessment in the elderly: The benefits of an online test battery

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Word count: (1500 max), 1 figure, 1 table

Abstract (200 words)

**Introduction** - Assessing an individual’s cognitive capacity is an increasingly important part of caring for the elderly. We sought to determine whether a novel online cognitive test battery could differentiate individuals with ambiguous cognitive scores; specifically, we asked which online test, or combination of tests, best categorizes individuals with ambiguous MoCA and MMSE scores.

**Methods** – 52 elderly participants completed 12 online tests on a touchscreen tablet computer, as well as a MoCA, and a Mini-Mental State Examination (MMSE).

**Results** – The MoCA categorized 73% of participants as clearly impaired or unimpaired. The addition of a single online task increased categorization to 94%. A multiple regression identified two other online tests that best predicted MoCA scores. The combination of scores from the three identified tests were highly correlated with MoCA scores. A regression also identified two online tests that best predicted MMSE scores but the categorization analysis was not performed because of a ceiling effect in MMSE scores.

**Discussion** – The addition of a single online test to the MoCA improved identification of individuals with ambiguous scores and a short battery of three CBS tests is a viable alternative to the paper-pencil tests currently used to monitor cognitive changes in older adults. This online testing battery may have significant consequences for care and quality of life in the aging population.

Assessing an individual’s cognitive capacity is an increasingly important part of caring for the elderly. Cognitive capacity assessments are used to determine the level of care an individual requires and assessment results have legal implications for determining whether an individual is capable of making decisions about property and personal care. Full cognitive capacity assessments are difficult and time-consuming to administer. Shorter versions can be used to gain a snapshot understanding of an individual’s capacity and to efficiently follow cognitive changes over time. Long-term monitoring of cognitive abilities is important for identifying fluctuations that may require modifications to an individual’s care plan. Currently, one of the most widely used tests for monitoring cognitive abilities is the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005). The popularity of the MoCA is largely due to how quickly it can be administered (less than 10 minutes) and its sensitivity to mild cognitive impairments which is known to be higher than similar tests such as the Mini-Mental State Examination (MMSE) (Gluhm et al., 2013). The MMSE was developed in 1975 as an efficient way to routinely evaluate psychiatric patients (Folstein, Folstein, & McHugh, 1975) and is still used to evaluate cognitive states by health-care professionals around the world.

One shortfall of paper-pencil tests like the MoCA and the MMSE is ambiguity about how to determine threshold (or ‘cut off’) scores (Nasreddine, Phillips, & Chertkow, 2012). For example, some studies have suggested that the threshold recommended by the MoCA may not be valid in aging populations and should be lowered (Damian et al., 2011; Gluhm et al., 2013; Malek-Ahmadi et al., 2015). Ambiguity about how scores should be classified can result in inappropriate changes to an individual’s care. In one recent study, an online cognitive battery of two tests was used to improve the classification of individuals with ambiguous MoCA scores (Brenkel, Shulman, Hazan, Herrmann, & Owen, 2017), suggesting that these tests may be capable of a more fine-grained classification of cognitive abilities than traditional paper-and-pencil approaches.

We used the Cambridge Brain Sciences (CBS) test battery (cambridgebrainsciences.com; Hampshire, Highfield, Parkin, & Owen, 2012) to extend the preliminary investigation and examine whether a more extensive battery of 12 cognitive tests can improve identification of individuals with cognitive impairments beyond the scope of traditional tests like the MoCA and the MMSE. The CBS test battery is a novel approach to cognitive testing and was developed based on standard neuropsychological tests. The tests are computerized and available online and individuals are able to access them without an examiner present. Additionally, the test items are randomized and difficulty levels scale with ability creating a unique test for the participant every time it is taken. In this study, we asked which CBS test, or combination of tests, best categorizes individuals with ambiguous MoCA and MMSE scores.

**METHODS**

**Subjects**

Participants were recruited from retirement homes and the general community in Toronto and London, Ontario. Participants over the age of 50 with the ability to provide informed consent were included in the study. Any participant who was unable to understand the instructions of the tasks was excluded. In total 52 participants (43 female) participated in this study. The study was approved by the University of Western Ontario Research Ethics Board. All subjects gave written informed consent to participate.

**Procedure**

All participants were asked to complete the twelve online tests from the Cambridge Brain Sciences (CBS) battery. Descriptions of each of the tasks can be found in the supplementary materials. The tasks were presented to participants on a tablet computer with a touchscreen and each was preceded by instructions and practice trials. Researchers were on hand to offer further clarification of instructions if necessary. Participants completed all 12 tasks in a random order and took as many breaks as necessary between tasks to prevent fatigue. After completing the CBS task battery, a MoCA (version 7.1 English) and MMSE (Folstein et al, 1987) were administered on paper in interview format with one of the authors (AS). All MoCAs and MMSEs were administered by the same person (AS). Participants also completed a demographic questionnaire on paper.

**RESULTS**

Fifty-two older adults with an average age of 81 years (62-97 years) completed the 12 CBS tests, a MoCA, and a MMSE. Only two participants did not complete all 12 tasks. One of these participants only completed half the tasks due to fatigue; the second completed only two tasks before losing interest and withdrawing. Scores on the MoCA ranged from 12-30 (mean=24.6) and scores on the MMSE ranged from 16-30 (mean=27.7). A summary of task scores can be found in Table 1.

Table 1. Summary of task scores and relevant population norms from 342 older adults aged 70-94. In this study, only 7 participants were younger than 70. For details about the named CBS tests, see supplementary materials.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Task** | **Scores** | | **Population norms**  **age 70-94** | |
|  | **Mean** | **SD** | **Mean** | **SD** |
| MoCA | 24.6 | 4.0 |  |  |
| MMSE | 27.7 | 2.8 |  |  |
| Double Trouble (CBS) | 9.4 | 11.9 | 17.8 | 11.2 |
| Odd One Out (CBS) | 11.4 | 3.5 | 13.4 | 2.4 |
| Spatial Planning (CBS) | 12.4 | 7.1 | 14.4 | 7.5 |
| Grammatical Reasoning (CBS) | 10.4 | 5.9 | 13.8 | 4.6 |
| Digit Span (CBS) | 4.8 | 1.8 | 6.8 | 1.6 |
| Token Search (CBS) | 5.8 | 1.7 | 6.3 | 1.9 |
| Paired Associates (CBS) | 3.5 | 0.9 | 4.3 | 1.0 |
| Spatial Span (CBS) | 4.3 | 1.2 | 4.9 | 0.9 |
| Feature Match (CBS) | 68.3 | 25.6 | 95.8 | 24.8 |
| Rotations (CBS) | 32.4 | 26.1 | 62.4 | 28.6 |
| Polygons (CBS) | 17.7 | 16.8 | 32.4 | 19.9 |
| Monkey Ladder (CBS) | 5.7 | 1.8 | 6.6 | 1.3 |

A step-wise multiple regression analysis showed that MoCA scores were best predicted by two CBS tests: Feature Match and Odd One Out, R2=0.65. Age was included as a factor, but did not significantly predict any variance over and above the tests themselves. On its own, age predicted 22% of the variance in MoCA scores (R2=0.22). A step-wise multiple regression performed on MMSE scores showed that Feature Match and Grammatical Reasoning best predicted MMSE scores and accounted for 38% of the variance. Age was included in this regression but did not explain a significant amount of variance over and above the task scores. On its own, age accounted for 8% of the variance in MMSE scores.

To determine whether level of education was related to MMSE or MoCA scores, a third regression was performed. The results showed that level of education did not explain a significant amount of variance in MMSE or MoCA scores. This is likely due to the high level of education in the sample and may account for the ceiling effect seen in MMSE scores (see Figure 1). In our sample, only one participant did not receive a high school diploma. The rest of the sample completed high school with 24 participants earning postsecondary degrees and 16 participants earning both postsecondary and postgraduate degrees.

Participant scores were then split into three categories based on MoCA scores (See Figure 1): unimpaired (n=25) MoCA score ≥26, borderline cognitive impairment (n=14) MoCA score 23-25, and impaired (n=12) MoCA score ≤ 22. The lower threshold of 22 was chosen based on an average of recommended thresholds from the previous literature (e.g. Damian et al., 2011; Gluhm et al., 2013; Malek-Ahmadi et al., 2015). This analysis was not performed on MMSE results due to the ceiling effect seen in these scores.

\*\*\* FIGURE ONE ABOUT HERE PLEASE\*\*\*

To replicate the analysis performed by Brenkel et al. (2017) each participant in the borderline group was reallocated to either the impaired or unimpaired groups based on their online test scores using the following procedure: If the score of a participant in the borderline group on one of the 12 tasks was less than or equal to the average score of the impaired group (on that task) they were categorized as impaired. If their score on a particular task was greater than or equal to the average score of the unimpaired group (on that task) they were classified as unimpaired. This procedure was conducted for each of the online tasks individually as well as all possible combinations of tasks. When multiple tasks were used, the borderline participants were only categorized if the direction of categorization was consistent across all tests in the combination.

The addition of one test (Spatial Planning) increased categorization of participants the most (to 94%), leaving only 3 participants in the borderline group. This single test categorized participants better than other single test or any combination of tests. In comparison, a test of equal difficulty (Spatial Span) left 5 participants in the borderline group. Test difficulty was determined based on scores from 327 participants age 71-80 collected as part of “The World’s Largest Sleep Study”. More information regarding these data can be found in the supplementary materials.

Participants’ scores on each of the three tests identified in our two analyses (Feature Match, Odd One Out, and Spatial Planning) were converted to z-scores and an average was calculated to create a composite. This composite score was strongly correlated with MoCA scores *r*=0.74 (*p*<0.001). In comparison, the composite score was less correlated with Mini-Mental State Examination (MMSE) scores (*r*=0.55, *p*<0.001; see Figure 1).

**DISCUSSION**

We investigated how an online cognitive test battery could be used to further identify cognitive impairment when the MoCA or MMSE returned ambiguous scores. Using a step-wise multiple regression we determined that the Feature Match and Odd One Out tasks best predicted MoCA scores. The categorization analysis showed that using one additional computerized test in conjunction with the MoCA resulted in classification of 94% of participants as impaired or unimpaired (compared to the MoCA alone – 73%). The addition of the Spatial Planning task provided more information about the participants’ complex executive function skills and allowed for a more fine-grained categorization. The advantage of being better able to classify individuals with ambiguous scores has implications for their treatment and quality of life. We were unable to perform this same analysis on MMSE results due to a ceiling effect in the score distribution suggesting that the MMSE may not be an appropriate test for highly educated, aging populations.

The composite score created from Feature Match, Odd One Out, and Spatial Planning was highly correlated with MoCA scores (*r*=0.74), indicating that these three tests may be an effective way to track cognitive changes in aging adults.

We did not replicate the results of Brenkel et al (2017) who found that the Odd One Out and Double Trouble tests best categorized borderline participants. There are a number of reasons that may account for the difference in results. First, Brenkel et al (2017) used a cut-off score of 27 rather than the score of 26 suggested by MoCA test developers and used in this experiment. Second, the participant populations were quite different. In this experiment participants were recruited from nursing homes, retirement homes, and the general population and the sample included many highly educated individuals. Brenkel et al (2017) recruited from a geriatric psychiatry outpatient clinic and included participants with known mood or major neurocognitive disorders. Finally, our participants completed the tasks on a touch screen tablet computer (iPad) while in the previous study, participants completed the tests with a mouse and a computer screen.

This study also explored the feasibility of using an online test battery with older adults. Statistics Canada predicts that by 2036, 25% of the Canadian population will be over 65 years of age (Statistics Canada, 2016). With an increasingly aged population, the ability to easily and effectively assess individuals is important. The CBS battery is conducive to such testing because it can be administered without the one-on-one interview format typical of current cognitive assessments. The CBS tests are also designed to produce novel versions of the test each time it is administered. The design of the CBS battery means participants can take these tests many times without practice effects and with minimal burden to administrators making it a good candidate for monitoring abilities over time.

As the population ages it is important to have an effective assessment of cognitive abilities in older adults that reduces administrator burden. The state-of-the-art CBS testing battery can provide such an assessment. The addition of a single CBS test to the MoCA can better identify individuals with ambiguous scores and a short battery of three CBS tests is a viable alternative to the current tests used to monitor cognitive changes in older adults. The next step is to gather data from a large sample of participants with known diagnoses to define accurate thresholds for this novel testing battery that can be confidently used with aging populations.

**Acknowledgements**

Special thanks to residents of Christie Gardens Apartments and Care in Toronto, Ontario and to Grand Wood Park in London, Ontario for their willingness to participate in our research. Thank you to Emily S. Nichols and Alexandra A. Pearce for their help with data collection.

**Competing Interests**

The online cognitive tests used in this study are marketed by Cambridge Brain Sciences Inc, of which Dr. Owen is the Chief Scientific Officer. Under the terms of the existing licensing agreement, Dr. Owen and his collaborators are free to use the platform at no cost for their scientific studies and such research projects neither contribute to, nor are influenced by, the activities of the company. As such, there is no overlap between the current study and the activities of Cambridge Brain Sciences Inc, nor was there any cost to the authors, funding bodies or participants who were involved in the study.

**Funding**

This project was funded by the National Science and Engineering Research Council and the Canada Excellence Research Chairs Program.

Figure Captions:

Figure 1. MoCA and MMSE scores are plotted here with horizontal lines indicating the thresholds used to differentiate the three groups. MoCA scores are differentiated using the method described here. MMSE scores are differentiated using the severity method as explained in the published MMSE scoring document. Correlations between the tests and composite scores are significant at p<0.001.