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 has become an increasingly important part of caring for the elderly. In this study, we sought to determine whether an online cognitive test battery could better differentiate individuals with ambiguous MoCA scores; specifically, whether those cognitive tests that best predicted Montreal Cognitive Assessment (MoCA) scores could be used to reclassify borderline participants as ‘impaired’ or ‘unimpaired’.

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

**Results** - When the MoCA was used on its own to classify participants into the three categories, 73% of participants were classified as borderline (i.e. neither clearly impaired nor unimpaired). The addition of a single computerized task increased categorization of patients to 94%. The classification accuracy of the MMSE was not improved by including additional online assessment, although the analysis was hampered by ceiling effects in this population of participants.

**Discussion** – As the population ages it is important to have a conclusive assessment of cognitive abilities in older adults. In this experiment, we have shown how the inclusion of a short battery of computerized tests in addition to the MoCA can better identify impaired and unimpaired individuals.

Here’s what I would do for my Discussion:

Discussion – The assessment of cognitive capacity in the elderly can be significantly improved by supplementing traditional paper and pencil tests of cognition such as the MoCA with a single online test of cognitive function, which may have significant personal and legal consequences.

Assessing an individual’s cognitive capacity has become 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 have been created that can be used to gain a snapshot understanding of an individual’s capacity and to follow cognitive health changes over long periods of time. Currently, one of the most widely used tests 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 is known to be higher than other similar tests, such as the Mini-Mental State Examination (MMSE). 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, as well as how to interpret scores that fall near that threshold. Ambiguity about how tests scores should be classified can lead to misdiagnosis of individuals and result in inappropriate changes to treatment. For example, the threshold recommended by the MoCA may not be valid in aging populations and some studies have suggested that it should be lowered for this population (Damian et al., 2011; Gluhm et al., 2013; Malek-Ahmadi et al., 2015). 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 such tests may be capable of a more fine-grained classification of cognitive abilities than traditional paper-and-pencil approaches.

In this study, we extended this preliminary investigation to examine whether a more extensive battery of 12 cognitive tests can further improve classification in traditional tests like the MoCA and the MMSE. Specifically, we asked which cognitive test, or combination of tests, best recategorizes individuals with ambiguous MoCA scores as ‘impaired’ or unimpaired’

**METHODS**

**Subjects**

Participants were recruited from retirement homes and the general community. 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 (cambridgebrainsciences.com). 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 (62-92 years) completed the 12 computerized 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=27.8). 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 | 27.8 | 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 |

The first analysis was to determine which of the 12 computerized tests best approximated the results of the MoCA assessment. A multiple regression analysis showed that MoCA scores were best predicted by two 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).

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 (see Figure 1). 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).

\*\*\* 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 of tasks were used, the borderline participants were only categorized if the direction of categorization was consistent across all tests in the combination. The analysis showed that the addition of one test (Spatial Planning) increased categorization of participants the most (94%), leaving only 3 in the borderline group. This single test categorized participants better than other single test or any combination of tests.

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 returned scores that were neither clearly impaired or unimpaired. Using a step-wise multiple regression we determined that the Feature Match and the 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.

The composite score created from these three tests was highly correlated with MoCA scores (*r*=0.74), indicating that such a computerized test battery may be an effective way to track cognitive changes in aging adults. There was less of a correlation with MMSE scores (*r*=0.55) and we see a ceiling effect in the distribution of scores suggesting that the MMSE may not be an appropriate test for aging populations.

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. The difference in results is likely due to our participants completing 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. For older adults who may not be familiar with computers, using a mouse to complete tasks may be too difficult. With a more intuitive touchscreen interface, older adults are better able to perform the tasks.

This study also explored the feasibility of using a computerized test battery in an older adult population. 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 use computerized test batteries is extremely important. Computerized tests do not require a one-on-one interview and therefore reduce the amount of time necessary to assess patients. Computerized tests also have the advantage of presenting a novel version of the test each time it is administered. By randomizing the test items, we can guarantee that the patient’s score is related to their abilities and not their memory of test items. As a result, participants can take these tests many times making the computerized tests a good candidate for monitoring abilities over time.

As with any type of test it is important that the test taker is as comfortable as possible throughout the session. In this study, we were concerned that older adults would have issues completing all 12 tasks due to fatigue, but only two participants were unable to complete the tasks. One participant did not complete the tasks due to frustration, and the other simply lost interest. Allowing all participants to take as many breaks as they needed resulted in no participant withdrawing due to fatigue. Moreover, the three tasks that we have identified (Spatial Planning, Odd One Out, and Feature Match) can be completed in less than 10 minutes minimizing any adverse effects. Frustration was also minimized in our study as the tasks were presented on a tablet computer rather than asking participants to coordinate mouse movements to a screen.

As the population ages it is important to have a conclusive assessment of cognitive abilities in older adults. In this experiment, we have shown how the inclusion of a short battery of computerized tests in addition to the MoCA can better identify impaired and unimpaired individuals.

**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.