Usability of the Virtual Supermarket Test for Older Adults with and without Cognitive Impairment

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Abstract. This study conducted a preliminary usability assessment of the Virtual Supermarket Test (VST), a serious game-based self-administered cognitive screening test for mild cognitive impairment (MCI). Twenty-four healthy older adults with subjective cognitive decline and 33 patients with MCI self-administered the VST and then completed the System Usability Scale (SUS). The average SUS score was 83.11 (SD = 14.6). The SUS score was unaffected by age, education, touch device familiarity, and diagnosis of MCI. SUS score correlated with VST performance (r = –0.496, p = 0.000). Results of this study indicate good usability of the VST.

Keywords: Age-related memory disorders, cognitive assessment screening instrument, computer games, dementia, mild cognitive impairment, neurocognitive tests, screening, self-evaluation

INTRODUCTION

Virtual reality (VR) and serious game applications have exhibited strong potential for differentiating between healthy and cognitively impaired older adults [1, 2] and their use as digital biomarkers has been proposed [3]. The Virtual Supermarket Test (VST) is a VR application with a low degree of immersion that has been used effectively to detect mild cognitive impairment across different populations and regions [4–11]. Empirical data from seven previous VST studies [4–10], such as lack of drop-outs and overall positive comments about the usability of the VST by study participants, indicate that the VST is usable and acceptable by its target audience. The successful validation of the latest fully self-administered VST version [4, 5] hinted at high usability as all participants were able to successfully operate the application despite not receiving any kind of help or guidance from an examiner. At the same time, a formal quantitative assessment of the VST’s usability had not been conducted.

This study is part of a series of studies to assess a new computerized testing paradigm for older adults with subjective cognitive decline (SCD), based on a self-administered serious game-based test, the VST. Previous studies have evaluated the diagnostic effectiveness [5] and the neurophysiological correlates [4] of the VST. The present study conducts a preliminary assessment of the VST’s usability, considering the importance of usability in technology adoption [12]. It focuses on assessing the usability in a sample of older adults with mild cognitive impairment...
MATERIALS AND METHODS

Virtual reality serious game-based cognitive screening test

The VST application has been described in detail in previous studies [4–10]. It features an interactive training session followed by a test trial that is repeated three times for a total of three test trials per VST administration. It features complex metrics including assessment of mistakes and speed, trajectory analysis and assessment of practice effects. It has been found to outperform gold standard pencil and paper cognitive screening tests, such as the Montreal Cognitive Assessment, in differentiating between MCI patients and healthy controls [5, 7–10]. It is aimed at activating a multitude of cognitive functions with the emphasis placed on executive function and navigation as demonstrated through correlations of VST performance with performance on established pencil and paper tests assessing these domains [7, 9, 10]. The need for simultaneous activation of different cognitive functions makes the VST challenging enough to correspond to the ability level of the target population (healthy older adults with SCD and MCI patients) while reducing ceiling effects. Figure 1 provides a screenshot of the VST digital environment.

System Usability Scale

The System Usability Scale (SUS) comprises ten questions scored in a 5-point Likert scale. Its score ranges from 0–100 and the average SUS score (50th percentile) according to SUS scores normal distribution is 68 [13, 14]. SUS scores between 71 and 84 are considered good and SUS scores of 85 and above are considered excellent [14, 15]. The SUS has been translated and validated for use in Greek adults.

Participants

This study was conducted in parallel to the study for the validation of the latest, fully self-administered version of the VST [5]. The study sample comprised healthy older adults with SCD and older adults with amnestic MCI. Exclusion criteria were: diagnosis of dementia or another major neurological or psychiatric disorder, illiteracy, health issues such as motor and vision difficulties that could interfere with the use of the VST, treatment with cholinesterase inhibitors or other drugs that can affect cognitive performance, alcoholism or drug abuse. Recruitment was conducted between April 2018 and April 2019 at the day centers of the Greek Association of Alzheimer’s Disease and Related Disorders (GAADRD) in Thessaloniki, Greece. MCI patients were paired randomly with older adults of similar age and education level, without MCI symptoms but with subjective memory complaints, to ensure a balanced sample. All participants provided informed consent. Diagnosis was conferred by a neurologist after a full neurological, neuropsychological and laboratory assessment. MCI diagnosis was based on Petersen criteria [16–18]. Participants with no objective impairment in neuropsychological testing were allocated to the SCD group.

Study protocol

Familiarity with touch devices was assessed with a binary question where participants were instructed to answer “Yes” if they could operate the touch device and do simple tasks (e.g., find a specific contact in the contacts app) unassisted. Participants were asked to complete the VST exercise on their own. The examiner prepared the tablet and launched the VST app but did not assist participants. After the administration of the VST, participants were asked to complete the Greek version of the SUS, which is a widely-used valid tool for usability assessment [19]. The overall procedure lasted approximately 45 minutes. This study protocol for assessing the usability of the
VST in parallel with its diagnostic utility, was specifically selected so the participants were not exposed to the VST app more than once before completing the SUS questionnaire. The study was conducted in accordance with the Declaration of Helsinki ethical guidelines and was approved by the Scientific and Ethical Committee of the GAADRD.

Statistical analysis

Statistical analysis was conducted with the SPSS (version 24.0) statistical software package [20]. Similar to a previous study [4], user performance on the VST was calculated using its core metrics: a) total mistakes conducted during the 3 VST test trials and b) average time needed to complete the 3 VST test trials. Comparisons between user groups were performed using Mann-Whitney U test. Results of these tests with a \( p \) value of less than 0.05 were considered as statistically significant. Pearson’s correlation analysis was used to determine the relationship between SUS score, VST variables, age, and education.

RESULTS

Demographic characteristics of participants

The sample included 24 healthy older adults with SCD and 33 MCI patients. Fifteen participants were male and 42 were female. Mean age was 67.21 years (SD = 5.095) ranging from 54 to 75 years. Subjects had a mean of 13.44 (SD = 2.739) years of formal education ranging from 9 to 21 years of formal education. No significant differences were observed between the SCD and MCI groups in age and education while significant differences were observed in Montreal Cognitive Assessment scores as expected. Similarly, no significant differences were discerned between participants with touch device familiarity and participants with no touch device familiarity in age and education. Demographic characteristics of participants are presented in Table 1.

SUS results

The average SUS score was 83.11 (SD = 14.6).
Table 1
Demographics characteristics of MCI patients and SCD

|                 | MCI (n = 33) | SCD (n = 24) | p     |
|-----------------|--------------|--------------|-------|
| Age, y          | 68.39 (4.53) | 65.58 (5.47) | 0.403 |
| Education, y    | 13.06 (2.88) | 13.96 (2.49) | 0.123 |
| Gender (M/F)    | 10/23        | 5/19         | 0.423 |
| MoCA            | 25.09 (2.97) | 27.87 (1.74) | 0.002*|

M, mean; SD, standard deviation. Age, education, and Montreal Cognitive Assessment (MoCA) scores were tested by Mann-Whitney U test, gender by Chi-square test (Fisher’s exact). *p<0.05.

Table 2
Correlations between SUS score, age, education, and VST variables

|                 | SUS          |
|-----------------|--------------|
| Age, y          | Pearson Correlation -0.070, Sig. (2-tailed) 0.607, N 57 |
| Education, y    | Pearson Correlation -0.010, Sig. (2-tailed) 0.940, N 57 |
| Average Duration for 3 trials | Pearson Correlation -0.496**, Sig. (2-tailed) 0.000, N 57 |
| Sum of Errors for 3 trials | Pearson Correlation -0.250, Sig. (2-tailed) 0.060, N 57 |

**Correlation is significant at the 0.01 level (2-tailed).

Group differences in SUS score
No significant differences were found between the SCI and MCI groups in SUS scores. Similarly, no significant differences in SUS scores were found between participants with touch device familiarity and participants without touch device familiarity.

Correlations between SUS score, VST variables, age, and education
Significant correlation ($r = -0.496$, $p = 0.000$) was found between SUS score and average time needed to complete the 3 VST test trials. No significant correlations were found between SUS score, age, education and total mistakes conducted during the 3 VST test trials. Correlations are presented in Table 2.

DISCUSSION
Computerized cognitive screening test designers have shifted their focus towards brevity and ease of administration during recent years [21]. Many tests feature gamification elements and tasks in virtual environments are being integrated in computerized tests [22]. Newer tests are often designed to be self-administered at home or in the clinic [23]. The lack of an examiner can render these tests vulnerable to the effect of poor usability on test performance. Thus, test designers have been conducting usability assessments on computerized tests that are either self- or examiner-administered [24, 25]. This follows the paradigm of conducting usability assessment of serious games and other applications that are designed to be used by older adults, often without any assistance [26, 27]. As the VST is a cognitive screening test that is modeled on a serious game, has received considerable research interest and has been found to perform very well across different populations, we conducted a preliminary assessment of its usability using the SUS. This assessment was conducted in order to provide quantitative support to our indirect qualitative assessment of its usability through our interaction with participants in all VST studies [4–10].

Virtual tasks have been used extensively to assess cognitive deficits [28–31]. The usability of virtual shopping tasks has received significant research interest however most of these studies were conducted on more immersive VR apps, utilizing either VR goggles or specialized equipment such as projection screens and sensors, and a large part of the usability assessment was specific to the immersive nature of these apps [28, 30, 31]. Relevant literature suggests that older adults may perform better on non-immersive platforms [31]; however, the usability of on non-immersive virtual tasks such as the VST has not been studied extensively. Assessing the usability of such tasks is crucial as, contrary to immersive VR, they do not necessitate expensive specialized equipment and thus they can easily be used by a large number of older adults.

The present study provides preliminary data supporting the usability of the latest, fully self-administered version of the VST for cognitive assessment. Our primary finding is that VST displays good usability [15] among older adults with or without cognitive impairment, as assessed by SUS, with its usability score (83.11) being at the 90th percentile of SUS scores normal distribution [13, 14]. VST performance (average time to compete the three VST test trials) affected usability. Usability was unaffected by age, education, touch device familiarity, and diagnosis of MCI. The correlation between usability, as expressed through SUS score, and VST performance, as expressed through average time to complete the exercise, raises the question of the causal relationship between these variables. It is unclear whether
participants who took longer to complete the VST test trials provided a lower usability score as they were frustrated by the long time it took them to complete the exercise or if there are underlying usability issues that affected their performance thus resulting in a longer time to complete the VST test trials.

Strengths of this study include a robust diagnostic procedure for assigning participants into groups [5] and the use of a well validated serious game application (i.e., the VST). Furthermore, the study sample is representative of the people who reach out to brain health services and present to memory clinics for assessment [5].

Limitations of this study include the inclusion of significantly more female participants. Furthermore, the study sample was recruited from a day centre for people with cognitive disorders thus all participants, even those who did not present with cognitive impairment, had concerns about their cognitive functioning. Therefore, they may differ from a sample of healthy older adults recruited from the wider community in the sense that they are expected to have a particular interest in brain health and thus be more engaged during the administration of the VST. Future directions comprise studies with more participants including healthy older adults with and without SCD for the quantitative and qualitative assessment of both usability and acceptability through standardized questionnaires and focus groups.

CONCLUSION

This study demonstrates that VST has good usability, and its usability remains unaffected by age, education, touch device familiarity, and diagnosis of MCI. Study results provide a strong incentive for further, more detailed usability assessment of the VST.

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CONFLICT OF INTEREST

The authors have no conflict of interest to report.

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