REPORT OF RESEARCH RESULTS

(a) **Title:**
Using Augmented Reality to Assess Cognitive Function in Older Persons

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(c) Summary:

Background: Dementia is increasing in prevalence globally. Existing paper-and-pencil-based cognitive tests may not comprehensively assess cognitive function in the six cognitive domains, and do not reflect the true cognitive functions in real-life situations, i.e. ecological validity. Virtual Reality (VR) has the potential to overcome these issues. Limited studies have been done to evaluate the use of VR in assessing the six cognitive domains in the primary care setting. Therefore, we have developed Cognitive Assessment using Virtual Reality (CAVIRE-2), a novel VR system to assess the six cognitive domains.

Aims: The study primarily aims to compare the VR performance of cognitively-healthy versus suspected cognitively-impaired older persons when they undertake the CAVIRE-2 assessment. The VR performance is defined as the score and the time taken to complete the CAVIRE assessment. The secondary aims are to compare the VR score versus the Montreal Cognitive Assessment (MoCA) score; and also to assess the participants' acceptability on using the CAVIRE-2 system.

Methods: A total of 110 participants aged between 65-84 years old were recruited from a public primary care clinic in Singapore. They were assessed using the MoCA. Those with a MoCA score of ≥ 26 were grouped as cognitively-healthy, while those with a MoCA score of < 26 were grouped as suspected cognitively-impaired. Subsequently, the participants underwent the CAVIRE-2 assessment. The scores and time taken to complete the CAVIRE-2 assessment were computed automatically by the system.

(d) Aims of Research:

Primary aim:
To compare the VR performance of cognitively-healthy versus suspected cognitively-impaired participants aged 65-84 years old when they undertake the CAVIRE-2 assessment. The VR performance is defined as the score and the time taken to complete the CAVIRE assessment.

Secondary aims:
1. To compare the VR score versus the MoCA score.
2. To assess the participants' acceptability in using the CAVIRE-2 system in the primary care setting.

(e) **Method of Research & Progression:**

The study was conducted from October 2020 to April 2022 at a public primary care clinic (polyclinic) located within the Outram estate in the southern region of Singapore. This polyclinic provides subsidized primary healthcare services to approximately 18,960 residents of varying ethnicity in the estate, of which 24.7% were aged 65 years and above in 2019. The in-house GeRiAtric serviCE (GRACE clinic) is a sub-specialized memory clinic to provide longer consultation time to assess older participants with suspected cognitive impairment.

Study Participants
The study participants are those who attend the polyclinic for medical consultation, in both the general clinic and the GRACE clinic. Visitors and accompanying persons of patients at the polyclinic were also be recruited if they satisfy the eligibility criteria: (1) aged between 65 and 84 years old, and (2) understood English (the medium of instruction in CAVIRE-2, and (3) willing to complete the questionnaires and the CAVIRE-2 assessment. Those with any of the following were excluded: pre-existing diagnosis of moderate to severe dementia, on any dementia medication; any disability which rendered them incapable of providing written informed consent; neurological deficits that might affect vision, hearing, speech or motor skills; or known motion sickness or epilepsy.

Sample Size Estimation
Based on the results of the feasibility study on the previous version of CAVIRE (CAVIRE-1) to assess difference in performance scores between the 2 groups, a sample size of at least 10 per arm is required with 95% confidence interval and 80% power, given the scores in Group 1 and 2 are 552 +/- 57.2 & 476.1 +/- 61.9 respectively. In anticipation of a wider span of MoCA scores, we have planned to recruit at least 50 participants for each group.

Recruitment and CAVIRE-2 Assessment
During the study recruitment period, the Research Assistant (RA) screened the eligibility of potential participants at the waiting area of the clinic, or via internal referral from study investigators. The RA explained the study protocol, obtained written informed consent, and confirmed the participants' eligibility criteria from their electronic medical records before administering the Montreal Cognitive Assessment (MoCA). Those with a MoCA score of ≥ 26 were grouped as cognitively-healthy, while those with a MoCA score of < 26 were grouped as suspected cognitively-impaired. The RA then gathered the participants' demographic data (age, gender, ethnicity, number of years of education).

Next, the participants were briefed on the VR procedure and equipment. With the help of the RA, the participants sat on a chair and put on the VR head-mounted device. The participants were then introduced to a tutorial session. This tutorial session allowed all participants, regardless of age, to familiarize themselves and feel comfortable in using their head and hand movements in the VR environment. Once the participants were ready, they proceeded to complete the 13 segments of the VR assessment. The scores and the time taken to complete each segment were automatically computed in the CAVIRE-2 system and were aggregated for their overall VR performance.

After the VR assessment, the participants provided feedback by filling in a questionnaire on their experience in using the VR system. The questions collected data on their (1) level of comfort throughout the VR test; (2) perception of completing daily living tasks in the virtual environment; and (3) level of motivation and interest on the use of virtual technology in general practice. For each question, the answers were rated on a Likert scale (from 1 to 5, corresponding from "strongly disagree" to "strongly agree").

Statistical Analysis
All statistical analyses were done by utilizing the SAS software. Summary statistics were calculated for the demographic characteristics, the scores and completion time for the MoCA, the scores and completion time for the VR tasks, and the scores for the feedback form respectively. The VR performance-indices (scores and completion time) were compared among those who are cognitively-healthy with those who are suspected cognitively-impaired. Pearson correlation was also calculated to compare the VR score and the MoCA. For all statistical analyses, the statistical significance level was set at P-value < 0.05.

(f) **Results of Research:**

A total of 110 participants aged between 65-84 years old were recruited: 60 participants in the cognitively-healthy group; 50 participants in the suspected cognitively-impaired group. Only one participant from the suspected cognitively-impaired group failed to complete the study due to apprehension during the administration of the MoCA questionnaire, constituting a dropout rate of less than 1%. No participant experienced any VR adverse effects while performing the VR tasks. The participant who dropped out from the study was excluded from the statistical analysis. Hence, statistical analysis was performed for 109 participants: 60

participants in the cognitively-healthy group; 49 participants in the suspected cognitively-impaired group.

Demographic characteristics were similar between the two groups of participants (cognitively-healthy versus suspected cognitively-impaired) in terms of gender, ethnicity, and housing as a surrogate measure of socioeconomic status. However, p-value was significant when comparing the education level between the two groups. A higher proportion of participants in the cognitively-healthy group went for Post-Secondary/Tertiary education compared to those in the suspected cognitively-impaired group.

In comparing the MoCA performance between the cognitively-healthy versus suspected cognitively-impaired groups, the p-values were significant for the MoCA score (p-value < 0.0001) and also the time taken to complete the MoCA (p-value < 0.0001). Similarly, in comparing the VR performance between the cognitively-healthy versus suspected cognitively-impaired groups, the p-values were also significant for the VR score (p-value < 0.0001) and also the time taken to complete the VR assessment (p-value < 0.0001). This shows that cognitively-healthy participants scored higher for both the MoCA and VR assessment, and also took a shorter time to complete both the MoCA and VR assessment, as compared to the suspected cognitively-healthy participants.

Pearson correlation showed that there is a moderately-strong correlation between the MoCA score and VR score: 0.6271 (p–value < 0.0001).

With respect to each of the six cognitive domains assessed in CAVIRE-2 (perceptual-motor function, executive function, complex attention, social cognition, learning and memory, and language), the cognitively-healthy participants scored higher than the suspected cognitively-impaired participants in all six cognitive domains (all p-values < 0.001). The cognitively-healthy participants also required less time to complete the VR tasks compared to the suspected cognitively-impaired participants in all six cognitive domains (all p-values < 0.001).

In assessing the acceptability of the participants towards the use of CAVIRE-2, the participants showed positive feedback (overall 80% score on the 5-point Likert scale).

(g) **Future Areas to Take Note of, and Going Forward**

Preliminary results show that participants in the cognitively-healthy group perform better than participants in the suspected cognitively-impaired group, in terms of VR score and also time taken to complete the VR assessment. The results apply to all six cognitive domains. Moreover, the performance of the participants in using VR to assess cognitive function is in line with that of the MoCA. Participants also showed positive feedback in using CAVIRE-2 in the primary care setting. Further analysis will be done to assess whether CAVIRE-2 is actually capable of differentiating the VR performances between the cognitively-healthy group and suspected cognitively-impaired group.

The current study focuses on the use of the English version of the CAVIRE-2 software. Moving forward, the study team has plans to evaluate the use of the Mandarin version software, as well as to develop the Malay version software. A separate study will also be initiated to evaluate the test-retest reliability of CAVIRE-2. There are also plans to improve the existing CAVIRE-2 system, and also adopt a less bulky VR setup.

In summary, CAVIRE-2 has the potential to be used as a screening tool for cognitive impairment in the primary care setting, replacing the traditional neuropsychological paper-and-pencil tests such as MoCA. Further developments will be done to enhance the CAVIRE-2 system, so that it can be validated as a cognitive screening tool which assesses the six cognitive domains.

(h) **Means of Official Announcement of Research Results**

Upon completion of the full statistical analysis, the results of this study will be submitted for publication in a reputable journal.

The study team is also planning to publicise the findings in the media to show the potential of virtual reality to assess cognitive function in the primary care setting.