

Virtual reality-based and conventional cognitive interventions in community-dwelling older adults: The moderating role of cognitive reserve

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Abstract

This study evaluated the efficacy of three community-based interventions for older adults: virtual reality cognitive stimulation, traditional cognitive stimulation and socioemotional competence training, while examining the moderating role of cognitive reserve (CR). The sample included 65 older adults attending a community facility who completed baseline and post-intervention neuropsychological assessments following a three-month intervention program. Linear mixed model analyses, which included baseline age as a covariate to account for group differences, revealed that individuals with lower and average CR improved across all interventions, whereas individuals with higher cognitive reserve showed greater gains in the virtual reality and traditional groups. These findings highlight the importance of personalized intervention approaches tailored to individual CR profiles.

1. Introduction

Population ageing represents a major public health challenge, particularly in Portugal, one of the oldest countries in the European Union, where more than 2.5 million individuals are aged over 65 years (Fundação Francisco Manuel dos Santos, 2024). A substantial proportion of older adults live alone, increasing vulnerability to loneliness and social isolation, factors consistently associated with cognitive decline and reduced cognitive functioning in later life. In this context, identifying effective community-based interventions to support healthy cognitive ageing has become increasingly important.

Cognitive reserve (CR), defined as the capacity to maintain cognitive functioning despite age-related or pathological brain changes, has been proposed as an important moderator of cognitive ageing and intervention responsiveness. Factors such as educational attainment, occupational complexity, and engagement in cognitively stimulating activities contribute to CR and may influence cognitive outcomes following intervention (Mondini et al., 2016). Among emerging intervention approaches, virtual reality (VR)-based cognitive stimulation has gained increasing attention due to its ability to provide immersive, engaging, and ecologically valid experiences that may enhance motivation and adherence compared with traditional interventions (Gamito et al., 2020). However, evidence regarding the effectiveness of VR interventions in community-based settings remains limited. In parallel, socioemotional interventions targeting emotional regulation

and social interaction may also indirectly support cognitive functioning (Wei et al., 2024), although their comparative efficacy remains unclear.

The present study aimed to evaluate the efficacy of three community-based interventions implemented in a community facility for older adults: a VR-based cognitive stimulation program (VR-CS), a traditional paper-and-pencil cognitive stimulation program (PP-CS), and a socioemotional competence training program (SECT). Additionally, the study examined whether baseline cognitive reserve, assessed using the Cognitive Reserve Questionnaire (CRQ), was associated with differential cognitive outcomes following intervention.

2. Methods

2.1. Participants

The sample consisted of 65 participants enrolled in a community multidomain program. Most of the sample were women (57 female). The sample was predominantly Portuguese (95.5%), with a mean age of 75 years-old ($SD = 5.20$). Most participants (15%) had 4 years of schooling corresponding to complete 1st Cycle of studies, while 13.5% had 9 years of schooling corresponding to the 3rd Cycle of studies. Two participants were excluded because of prior neurological diagnoses. Group sizes were unequal, with the paper-and-pencil group (PP-CS; $n = 33$) being significantly larger than both the virtual reality (VR-CS; $n = 18$) and socioemotional groups (SECT; $n = 14$). No statistically significant differences in schooling were found across groups ($p > .05$). A statistically significant difference was found for age ($p = .021$), indicating that participants in the VR-CS group were younger than participants in the PP-CS group. Mean ages by group were as follows: VR-CS ($M = 72.1$, $SD = 4.83$), PP-CS ($M = 76.6$, $SD = 5.01$), and SECT ($M = 75.4$, $SD = 5.32$). To account for this baseline imbalance, age was entered as a covariate in the subsequent linear mixed model analyses.

2.2. Measures

- Addenbrooke's Cognitive Examination – ACE-III (Peixoto et al., 2013)
- Subjective Memory Complaints Questionnaire – SMC (Ginó et al., 2010)
- Instrumental Activities of Daily Living – IADL (Araújo et al., 2008)
- Geriatric Depression Scale – GDS-15 (Barreto et al., 2003)
- Satisfaction With Life Scale – SWLS (Diener et al., 1985)
- Cognitive Reserve Questionnaire – CRQ (Rami et al., 2011; Sobral et al., 2014)

2.3. Procedures

After approval from the institutional ethics committee and informed consent, participants completed a baseline neuropsychological assessment and were subsequently allocated to one of three intervention groups. All interventions were conducted twice weekly in about one-hour sessions over a three-month period, with equivalent frequency and duration across conditions. The VR-CS group used the Systemic Lisbon Battery (Gamito et al., 2020) in a non-immersive desktop-based setup to train cognitive functions through ecologically valid tasks, while the PP-CS group completed traditional cognitive stimulation exercises targeting domains such as attention, memory, language, and executive functioning. The SECT group participated in group-based activities focused on emotional regulation, communication, self-awareness, and problem-solving. Sessions were conducted by trained psychologists, and participants completed a post-intervention

neuropsychological assessment using the same measures applied at baseline. Figure 1 describes the procedure in this study.

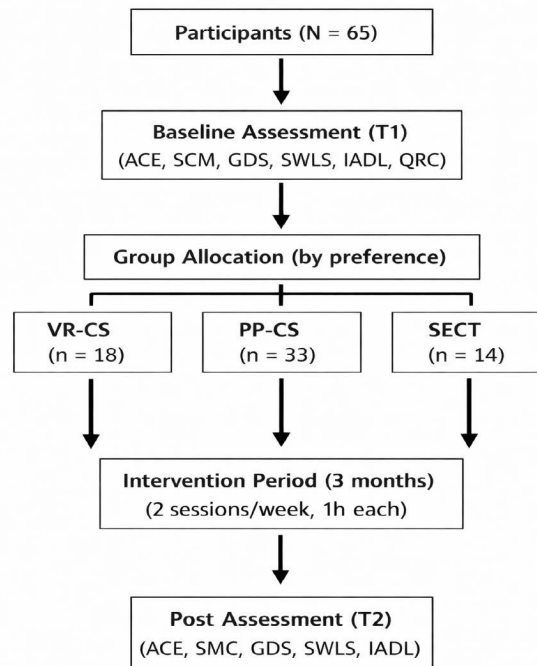


Figure 1: Procedure followed in this study.

3. Results

Linear mixed model analyses, controlling for baseline age, revealed a significant overall improvement in global cognitive functioning (ACE) from pre- to post-intervention ($F(1, 67) = 28.21$, $\eta p^2 = .30$, $p < .001$). No significant main effects of Group ($F(2, 67) = 1.39$, $\eta p^2 = .04$, $p = .256$) was observed. The main effect of cognitive reserve approached significance ($F(1, 67) = 3.87$, $\eta p^2 = .05$, $p = .053$), indicating differences better cognitive performance among participants with higher cognitive reserve. Importantly, a significant TimePoint $\times$ Group $\times$ CRQ interaction emerged ($F(2, 67) = 5.71$, $\eta p^2 = .15$, $p = .005$), showing that cognitive reserve moderated intervention outcomes. Participants with lower and average CR improved across all interventions, whereas individuals with higher CR showed attenuated gains in the socioemotional competence training group (SECT), while improvements remained significant in the VR-CS and PP-CS groups.

For subjective memory complaints, higher CR was associated with fewer complaints overall ($F(1, 67) = 4.27$, $\eta p^2 = .06$, $p = .043$). A significant TimePoint $\times$ Group interaction was also observed ($F(2, 67) = 5.14$, $\eta p^2 = .13$, $p = .008$). Post hoc analyses indicated that the SECT group showed a significant increase in subjective memory complaints following the intervention ($p = .012$), whereas no significant changes were found in the VR-CS or PP-CS groups ($p = .244$). No significant effects were observed for depressive symptoms, life satisfaction, or their interactions with cognitive reserve and intervention group (all p 's $> .05$). Inferential analyses were not conducted for IADL scores due to limited variability in the data.

4. Conclusion

This study examined the effects of three community-based interventions for older adults: VR-based cognitive stimulation (VR-CS), traditional paper-and-pencil cognitive stimulation (PP-CS), and socioemotional competence training (SECT), with a particular focus on the moderating role of cognitive reserve (CR). Overall, participants demonstrated improvements in global cognitive functioning following intervention, although the magnitude of these gains varied according to intervention type and baseline CR. Individuals with lower and average CR benefited across all intervention modalities, whereas participants with higher CR showed greater responsiveness to the cognitively demanding VR-CS and PP-CS interventions. In contrast, socioemotional competence training appeared to provide indirect cognitive benefits particularly for individuals with lower CR, potentially through mechanisms related to emotional regulation, self-efficacy, and social engagement. The increase in subjective memory complaints observed in the SECT group may reflect enhanced metacognitive awareness rather than actual cognitive decline. These findings highlight the importance of personalized and multidimensional intervention approaches tailored to individual cognitive reserve profiles. However, the results should be interpreted cautiously due to the non-randomized preference-based allocation design, the unequal group sizes, and the baseline age differences between groups, which, despite statistical adjustment, may still constrain causal interpretation, emphasizing the need for future randomized controlled studies with larger samples.

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