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Original Article

Effect of Video Games on Cognitive Performance and Problem-Solving Ability in the Aged with Cognitive Dysfunction: A Randomized Clinical Trial

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Abstract

Background: Mild cognitive impairment is a common aging phenomenon, and the absence of problem-solving abilities significantly contributes to memory decline. This study aimed to investigate the effect of video games on cognitive performance and problem-solving ability in the elderly with mild cognitive impairment.

Methods: In 2023, a double-blind, randomized clinical trial was done on mild cognitive impairment aged randomly divided into control and intervention groups with permuted blocks randomization. The participants in the intervention group played selected smartphone video games thrice a week for 12 weeks, but the control group did not do any intervention. Mini Mental Status Examination and Problem-solving Questionnaire were completed before, 8 weeks after the start, and 4 weeks after the end of the intervention. Statistical tests were done at the significance level considered less than 0.05 and analyzed in SPSS version 16.

Results: The mean±SD age of the 60 elderly participants who finished the study was 71.43±2.59. The mean±SD scores of cognitive performance and problem-solving ability improved in the intervention group (25.18±0.93 and 21.15±1.36) but worsened in the control group (19.43±0.76 and 13.72±1.98) ($P<0.001$). Before the intervention, no significant difference was observed between both groups in cognitive performance and problem-solving ability. However, there was a significant difference 8 weeks after the start and 4 weeks after the end of the intervention ($P<0.001$).

Conclusion: Playing video games thrice a week for 12 weeks can improve cognitive performance and problem-solving ability in the elderly with mild cognitive impairment. This approach is suggested for implementation.

Trial registration number: IRCT20211110053030N2.

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Keywords ● Video games ● Cognitive dysfunction ● Elderly

What's Known

- Most studies have been based on active exercises and were done by special facilities in hospitals or rehabilitative centers, while no study aimed at investigating the effect of video games on cognitive performance and problem-solving ability based on personal smartphones at home in elderly with mild cognitive impairment.

What's New

- Playing video games thrice a week for 12 weeks in the elderly with mild cognitive impairment can improve cognitive performance and problem-solving ability. This approach is suggested for the elderly who suffer from mild cognitive impairment.

Introduction

The global healthcare system faces challenges due to the rising life expectancy and declining death rates in the last two decades, with the elderly population predicted to surpass 22% by 2050 and 25% by 2030 in Iran.[1] Aging causes changes in body organs, leading to disease in the elderly, including disturbances in cognitive status and memory function.[2] Cognitive impairments in over 65-year-olds are classified as mild, moderate, and severe, with the latter being a predisposing factor for Alzheimer's Dementia (AD).[3] Mild Cognitive Impairment (MCI), characterized by brain tissue alterations, results in a decline in Cognitive Performance (CP), impacting memory, information processing speed, overall performance, and quality of life.[4] MCI is characterized by a decline in cognitive function, with symptoms including restlessness, speech disorder, depression, and information processing errors,[5, 6] which can lead to complications such as attention disorder, memory loss, speech changes, reduced daily activity performance, impaired judgment, and difficulty in problem-solving.[7]

Non-drug treatments such as cognitive rehabilitation are considered technological advancements and potential treatments for the elderly.[5, 8] Technology offers innovative ways to showcase CP promotion activities, such as video games (VGs) with moving images and audio feedback, for increased appeal.[9, 10] Previous studies show that VGs, which involve physical exercises, group participation, and special devices, can improve balance, fall risk, and quality of life in aged individuals.[10, 11] Promoting technology use involves understanding elderly needs, designing elderly-friendly software, and improving comprehension and memorial approaches by familiarizing elderlies with technology.[12]

One important goal of learning is the ability to solve problems. Problem-solving ability (PSA) is crucial in aging societies, as it measures CP in the elderly and provides feedback on learning outcomes.[13] In people with MCI, PSA decreases.[7] Disruption in PSA can lead to mental disability and negative effects on independence.[14] Effective PSA helps elderly individuals manage stress and promote self-care, self-efficacy, and health literacy.[15, 16] VGs have been shown to alleviate social isolation, promote energy, happiness, and communication in senior households, particularly with chronic heart failure, and improve quality of life.[16, 17] Active and outdoor exercises for older people were mostly studied in specialized facilities and with expensive transportation.[16, 17]

No research has examined the effects of VGs on CP and PSA in older MCI patients using personal smartphones at home. Thus, this study examined how VGs affect CP and PSA in older MCI patients.

Materials and Methods

Study Design

This was a double-blinded randomized clinical trial conducted in 2023 and applied permission from the Ethics Committee of Ilam University of Medical Sciences (IR.MEDILAM.REC.1402.094) and Iranian Clinical Trials Center code (IRCT20211110053030N2).

Setting and Participants

The study population was selected among the elderly referring to the Neurology Clinic of Emam Khomeini Hospital in Ilam province, using a convenience sampling method by considering inclusion criteria consisting of age 65 years and higher, ability to read and write, having a smartphone with an Android operating system with a screen size of more than 4 inches, obtaining a score between 18 to 23 in Mini-Mental Status Examination (MMSE), obtaining a higher score than eight in the Geriatric Depression Scale- Short Form (GDS-SF), obtaining a score higher than 68 in the System Usability Scale (SUS). Exclusion criteria included unwillingness to resume the research, history of performing VGs in the last 3 months, absence of more than two sessions, using cholinesterase inhibitors or antidepressants and anticonvulsants, being hospitalized during the study, and death.

Sample Size

According to the research by Eggenberger and colleagues,[18] the mean±SD of brain executive function before intervention was 44.7±7.47, and after intervention, it was 50±6.27 based on the comparison of the two mean formulas by considering the first error type of 0.05, the power of 0.80 that reported 25 participants for each group. Thus, by accounting for an attrition rate of 20%, the eventual number of participants in each group was determined to be 30.

$$N = \frac{\left(Z_{1-\alpha/2} + Z_{1-\beta}\right)^2 (\sigma_1^2 + \sigma_2^2)}{(m_1 + m_2)^2}$$

$$N = \frac{(1.96 + 0.842)^2((7.47)^2 + (6.27)^2)}{(44.7 - 50)^2}$$

$$= 25 * 0.20 = 30$$

Randomization and Blinding

Participants were randomly divided into control and intervention groups using four permuted blocks randomization. The researchers assigned randomized codes to sealed envelopes, which participants then picked. The study ensured that participants and the research team had no access to allocation. The expert trained and supervised participants and investigated any ambiguities or disturbances in the intervention.

Statistical analysts received the coded data without knowing the intervention type.

Measurements, Validity, and Reliability

The first tool was the data gathering form, which included the variables of age, sexuality, marital status, level of education, number of kids, occupation, hypertension, and diabetes.

The second tool was the MMSE, designed by Folstein and colleagues to evaluate cognitive impairment in the elderly. All questions have total scores ranging from 1 to 30. A total score of 24 and above indicates the absence of cognitive impairment, while a score of 18 to 23 indicates the presence of MCI, a score of 10 to 17 indicates moderate cognitive impairment, and a score of less than 10 indicates AD. To check the validity and reliability of the original and Persian versions of this tool, the content validity ratio (CVR) was 0.86, 0.89, and the content validity index (CVI) was 0.84 and 0.85, respectively.[19, 20]

The third tool was the Problem-solving Questionnaire (PSQ) designed by Cassidy and colleagues to investigate PSA. This questionnaire has 24 questions, which are graded as yes (one point), don't know (half a point), and no (no point), and the total score is 0 to 24. Higher scores than 18 mean better qualification in the PSA. To check the validity and reliability of this tool's original and Persian versions, CVR was 0.71, 0.74, and CVI was 0.78 and 0.81, respectively.[21, 22]

The fourth tool included the GDS-SF, which Yesavage and colleagues designed for investigating depression in the elderly. It has 15 questions, each with a score of zero and one. The total score of this questionnaire is from 0 to 15, with 0 to 4 indicating no depression, 5 to 8 as mild depression, 9 to 11 as moderate depression, and 12 to 15 as severe depression. To check the validity and reliability of this tool's original and Persian versions, CVR was 0.76, 0.90, CVI was 0.93, and 0.83, respectively.[23, 24]

The fifth tool included the tool for measuring the Positive and Negative Aspects Scale (PANAS) of VGs, which was designed by Watson and colleagues to investigate the impact of VGs and has twenty questions (10 positive and 10 negative attitudes), which are graded on a Likert scale from 1 (not at all) to 5 (very much). The total score of this questionnaire is 10 to 100, according to the scoring range of its aspects. If the person's score in response to questions of positive dimensions is more than doubled his score in response to questions of negative dimensions, the game is considered a suitable and acceptable game to use. To check the validity and reliability of the original version of this tool, CVR was 0.82, and CVI was 0.88.[25]

The sixth tool included SUS, which Brooke and colleagues designed to assess a person's ability to use new visual technologies. This questionnaire has 10 graded questions using a Likert scale from 0 (completely disagree) to 4 (completely agree). The maximum score of this questionnaire is 40, multiplied by 2.5 to make it 100 to facilitate the interpretation of the results. In the elderly population, scores of 68 and above indicate the usability of the visual system in them. To check the validity and reliability of the original version of this tool, CVR was 0.81, and CVI was 0.80.[26]

PANAS and SUS instruments had not been validated in Persian. Thus, employing the usual Backward-Forward approach and validity calculations on 30 elderlies with MCI, Persian PANAS CVR, and CVI were 0.91, 0.86, and SUS 0.82, 0.87, respectively.

Outcome

In this study, two outcomes were considered. The primary outcome was CP, which was assessed by MMSE. The secondary outcome was PSA, which was evaluated by PSQ.

Intervention

After the criteria assessment by a geriatric psychiatrist, the research team selected six VGs based on previous studies on Android operating systems. It examined their positive and negative dimensions using the PANAS questionnaire. Three VGs were chosen by a senior psychology and technology expert, ensuring the most suitable environment, competition, and positive excitement with minimal violation, cruelty, stress, adverse effects, and cultural familiarity. The intervention group played three selected games for 12 weeks: Classic Sudoku, Golf, and Archery. The games were installed on personal mobile phones using the Online Game Launcher software. Participants could only play three sessions per week, each lasting 45 min, during even days from 6 am to 10 pm The application also created daily notifications for doing VGs in Persian. After the 12th week, the Online Game Launcher closed the selected VGs due to the end of games, preventing participants from playing the games and installing new ones until 4 weeks after the study. In contrast, the control group received periodic examinations of CP changes, adherence to medication programs, and monthly blood sugar and blood pressure measurements.

For data filling, MMSE and PSQ questionnaires were completed before, 8 weeks after the intervention, and 4 weeks after the intervention by secretary phone call and saved on Online Game Launcher software

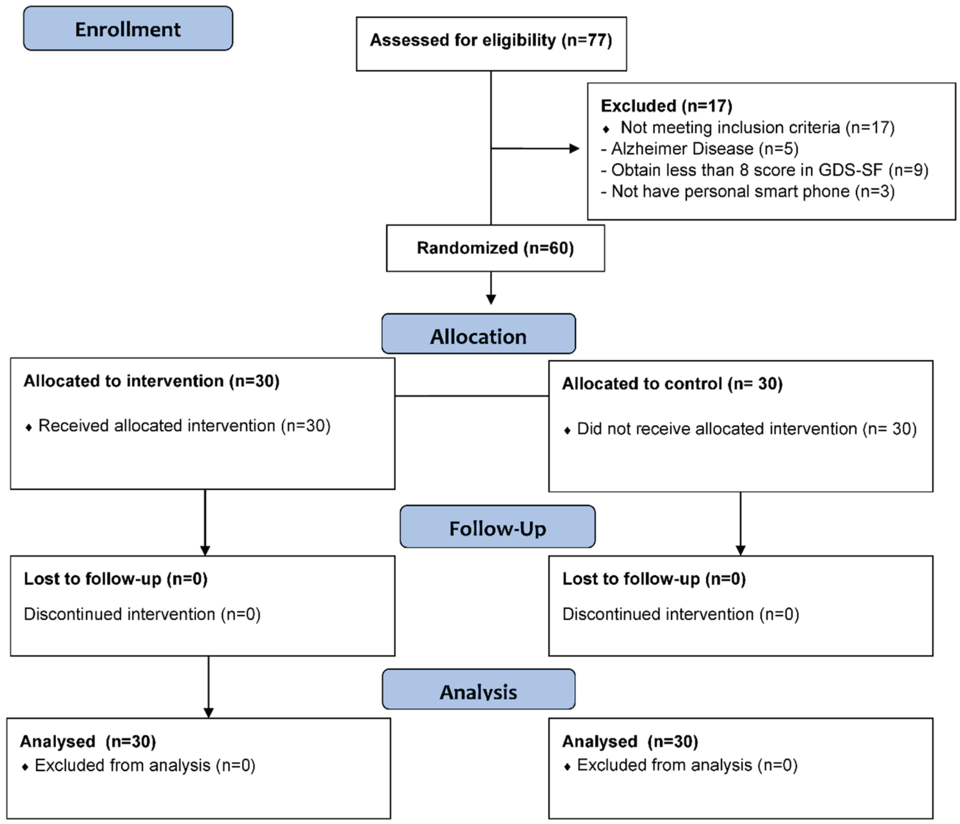

Figure 1: The procedure of selecting and conducting the research protocol based on control and intervention groups

by participants' codes. The statistical analyst analyzed the coded data after the study without knowing the intervention type (figure 1).

Ethical Considerations

The study adhered to ethical standards, including obtaining the ethical code from the Ilam University of Medical Sciences, registering with the Iranian Registry of Clinical Trial, obtaining informed consent, maintaining confidentiality, and adhering to the Declaration of Helsinki.

Statistical Analysis

This research used mean±SD to describe quantitative data and the number and percentage of qualitative factors. The Kolmogorov-Smironov test was used to analyze the normal distribution at 0.05. Chi square, Fisher Freeman Halton, and One-Way Repeated Measure ANOVA were also employed to examine the data. When the One-Way Repeated Measure ANOVA was significant, the *post hoc* (LSD) test was utilized for multiple/pairwise comparisons. All analyses were done by SPSS version 16 at a significance level of less than 0.05.

Results

The Kolmogorov-Smirnov (K-S) test was used to determine variable normality in the intervention and control groups. The test findings showed that all variables had a normal distribution. The mean±SD of the age distributions was 71.43±2.59. The Chi square test showed no significant demographic difference between the control and intervention groups (table 1).

The research found no significant difference in CP scores between control and intervention groups before the intervention (P=0.08), but significant differences were observed 8 weeks and 4 weeks after the end of intervention (P<0.001). Between the control and intervention groups, mean PSA scores were not substantially different before the intervention, but significant changes were seen 8 weeks and 4 weeks after the end of the intervention (P<0.001). According to One Way Repeated Measure ANOVA, the control and intervention groups had significantly different increases in average scores of CP (P<0.001) and PSA (P<0.001) over the research period (table 2).

The mean difference scores of CP and PSA for each group in the three time periods in the research revealed that the control group had less variance, whereas the intervention group had more. The *post hoc* (LSD) test resulted in a significant difference in CP and PSA levels in the intervention group after 12 weeks of VGs (P<0.001), while the control group showed no significant difference (P>0.05) (table 3).

Table 1: Presenting the frequency of aged participants in the study by demographic variables in the intervention and control groups

Variable		Intervention	Control	P value#
Age	65 to 74 (Young Elder)	19 (63%)	22 (73%)	0.11
	75 to 84 (Elder)	11 (37%)	8 (27%)	
	P value*	0.53	0.89	
Sex	Male	18 (60%)	19 (63%)	0.49
	Female	12 (40%)	11 (37%)	
	P value*	0.19	0.41	
Marital status	Widower	14 (47%)	6 (20%)	0.70
	Married	16 (53%)	24 (80%)	
	P value*	0.31	0.21	
Level of education	Elementary	14 (47%)	13 (43%)	0.52
	Secondary School	2 (6%)	7 (24%)	
	High School	3 (10%)	2 (6%)	
	Diploma	11 (37%)	8 (27%)	
	P value*	0.63	0.54	
Kids	1 to 3	7 (24%)	4 (13%)	0.82
	More than 3	23 (76%)	26 (87%)	
	P value*	0.35	0.49	
Occupation	Free	9 (30%)	14 (47%)	0.40
	Retired	21 (70%)	16 (53%)	
	P value*	0.51	0.42	
Hypertension	Yes	22 (73%)	25 (84%)	0.60
	No	8 (27%)	5 (16%)	
	P value*	0.24	0.41	
Diabetes	Yes	26 (87%)	20 (67%)	0.28
	No	4 (13%)	10 (33%)	
	P value*	0.88	0.71	

#Chi square test; *Kolmogorov-Smironov; The level of significance was considered to be less than 0.05.

Table 2: Comparing the mean level of primary variables at three distinct times in the intervention and control groups

Variables		Mean±SD			Time effect in each group, P value *	One Way Repeated Measure ANOVA P value *			P value#		
		T0	T1	T2		Group effect	Time effect	Interaction time*group	T0	T1	T2
CP[*1]	Control	21.02±1.02	20.16±0.54	19.43±0.76	F=2791 P<0.001	F=234.86 P<0.001	F=24.49 P<0.001	F=67.73 P<0.001	0.08	0.01	<0.001
	Intervention	20.94±0.87	22.77±1.14	25.18±0.93	F=548.22 P<0.001						
PSA[*2]	Control	17.48±1.63	15.81±1.03	13.72±1.98	F=364.41 P<0.001	F=6.32 P<0.001	F=45.49 P<0.001	F=122.15 P<0.001	0.06	0.01	<0.001
	Intervention	17.03±2.14	18.28±1.68	21.15±1.36	F=78.70 P<0.001						

CP: Cognitive performance; PSA: Problem solving ability; *1: MMSE tool used for assessment and scoring (score ranged from 1 to 30). *2: PSQ tool used for assessment and scoring (score ranged from 1 to 24). T0: Before the intervention; T1: Eight weeks after the start of the intervention; T2: Four weeks after the end of the intervention; *One Way Repeated Measure ANOVA; #Fisher Freeman Halton test; The level of significance was considered to be less than 0.05.

Discussion

This research found a statistically significant difference in CP and PSA mean scores following VGs. VGs improved CP and PSA in elderly MCI patients.

The current study's results are consistent with Xue and colleagues' single-blind RCT on the effects of visual exercises based on VGs in Microsoft Kinect on CP and depression in 72 elderly men with MCI across 8 weeks. Their investigation found that VGs lowered depression and improved CP.[27] Both trials used VGs to improve CP in older MCI patients. In the current study, time lasted 12 weeks. It was double-blind, used a personal smartphone, an expert selected games, was implemented in both genders, and questionnaires were filled out thrice. Pereira and colleagues ran a single-blind RCT study to investigate the effect of VGs on CP and the psycho-social status of 40 elderly thrice a week for 12 weeks. Its results

Table 3: Comparison of the mean difference of study primary outcomes at three specific times in the intervention and control groups

Outcome	Group	Time		Mean±SD	%95 CI (lower to upper)	P value*
CP	Control	T0	T1	0.86±0.48	0.63 (-0.5 to 1.1)	0.09
			T2	1.59±0.26	1.37 (-0.2 to 2.1)	0.08
		T1	T2	0.73±0.22	0.84 (-0.1 to 1.5)	0.11
	Intervention	T0	T1	-1.83±0.27	-1.77 (-2.1 to -1.5)	0.001
			T2	-4.24±0.06	-4.19 (-4.4 to -3.9)	0.001
		T1	T2	-2.41±0.21	-2.56 (-3.1 to -1.9)	0.001
PSA	Control	T0	T1	1.67±0.6	1.74 (-0.6 to 2.1)	0.08
			T2	3.76±0.35	3.91 (-0.3 to 6.8)	0.07
		T1	T2	2.09±0.95	1.98 (-0.9 to 3.9)	0.08
	Intervention	T0	T1	-1.25±0.46	-1.31 (-2.3 to -0.7)	0.001
			T2	-4.12±0.78	-4.29 (-4.9 to -3.3)	0.001
		T1	T2	-2.87±0.32	-2.44 (-2.9 to -2.1)	0.001

CP: Cognitive performance; PSA: Problem solving ability; T0: Before the intervention; T1: 8 weeks after the start of the intervention; T2: 4 weeks after the end of the intervention; CI: Confidence interval; **Post hoc* (LSD) test; The level of significance was considered to be less than 0.05.

showed that after conducting VGs, CP scores, and psycho-social status improved in the elderly, which is consistent with the present study's findings.[28] Both studies revealed that VGs improved elderly CP and psychosocial status. Individuals in their research had upper limp dysfunction, no cognitive impairment, and three weekly one-hour Microsoft Kinect outdoor VGs sessions. Once the experiment ended, study features were examined. However, the present study's individuals had MCI; its target device was a personal smartphone, and its variables were measured during and 4 weeks after the intervention to monitor VGs' effects on CP and PSA. A quasi-experimental study by Jirayucharoensak and colleagues found that using VGs improved the frontal lobe and CP function in healthy elderly and those with MCI.[29] The study used personal smartphones for the intervention, which took place three times a week for 8 weeks, with participants completing cognitive instruments before and after. The current study, which lasted 12 weeks, used personal smartphones for the intervention, with double-blind allocation and no need to leave home for environmental reasons. Both studies showed the appropriate effect of VGs on brain function and CP in both genders. The quasi-experimental study by Cicek and colleagues found no change in CP, mood, or decision-making ability after 6 weeks of group VGs in female elderly with MCI, which contradicts the current research.[30] The 41-person research was comprised solely of female living house residents. The sample allocation was unclear; the sessions were 15 min long and held weekly, the inclusion criteria were constrained, and the instruments were unrelated to the research population. However, the present 12-week trial comprised both genders was double-blind and utilized geriatric measures for assessment.

Regardless of the significance of the difference, the growth rate of CP and PSA in the period of 4 weeks after the end of the intervention was higher than 8 weeks after the start of the intervention. The reasons for this phenomenon can be attributed to the longer-lasting effects of VGs, the activation of the visual game network, and creative solutions in the brains of the participants,[31] as well as the effect of VGs on preventing the decline of cognitive function and improving neuromuscular coordination.[32] Unlike the methods used in previous studies, the importance of intervention shows that the effects of playing VGs have increased over time. Non-pharmacological and cost-effective VGs improve CP, balance, walking status, depression, and social communications in elderly MCI patients and reduce fall risk, social isolation, and memorial dysfunctions.[30, 32, 33]

The low CP and PSA scores have led to a reduction in the amount of self-care and observed health promotion behavior, increased drug poisoning, and care burden on their caregivers, which were shown clinically significant in the studies on elderly with MCI.[34, 35] Decreased learning and memorial impairment are common phenomena in old age that causes a negative impact on quality of life, PSA, and social interactions in the elderly with MCI.[17] Moradi and colleagues found that VGs improved visual memory and logical function as a factor in problem-solving ability and perception in forty elderly people without cognitive impairment in a rehabilitation center, consistent with the current study.[36] In their study, the intervention lasted 4 weeks, participants did not have cognitive disorders, and an expert for elderly suitability did not evaluate the game;

in the current study, selected VGs were done at home, the intervention lasted 12 weeks, and participants had MCI. Two studies found that VGs improve memory and decision-making, which affects problem-solving. Moreover, Yu and colleagues' RCT on 347 rehabilitation center participants found that computerized cognitive training preceded by physical exercise improved frailty status and cognitive function in the elderly. VGs increased CP, frailty status, memorial capacities, and PSA, which is consistent with the current study.[37] Their study included 90-min rehabilitation sessions twice a week for 12 weeks under the direction of geriatric nurses. In contrast, our research conducted VGs at home, followed up throughout the intervention, and examined genre selection. Both studies found that VGs improved sensory functioning, balance, and PSA in older people. In addition, Khushnood and colleagues' double-blind RCT on the effects of VGs on balance and CP in 90 elderlies with cognitive impairment after cerebrovascular accidents found that the intervention improved balance and CP, supporting present findings.[38] VGs were done by Nintendo in a specific center twice a week for 8 weeks and lasted 30 min each; while in our study, intervention lasted three times a week for 12 weeks, and participants did not have to leave home.[3] CP improvement as a factor connected to PSA was a consistent finding in the two investigations. The common feature of the two studies was the positive effects of the intervention on the improvement of CP as a factor related to PSA as a beneficial intervention in this age group.

Newly playing VGs enhances CP and PSA in the elderly. Solving issues in old age improves memory, decision-making, independence from everyday activities, and social connection.[39] Various research studies have found a positive correlation between the levels of CP and PSA and the executive functioning and quality of life of elderly people.[2, 13] As an additional benefit, VGs also help the elderly engage with family and the outside world and increase their executive function, which promotes PSA in MCI patients.[39]

A small sample size limited the study's generalizability to society. Next, the participants' education level limited its generalizability compared to older adults with higher education. The study's merits were using mobile phone-based VGs as an economical and up-to-date therapy, eliminating the elderly's need to leave the home and regular follow-up.

Conclusion

Playing VGs thrice a week for 12 weeks in the elderly with mild cognitive impairment can improve CP and PSA. As a novel intervention, using VGs enhances older adults' memory and problem-solving skills.

Future studies should focus on elderly populations with mental and physical disorders to reduce cognitive issues and improve their ability to overcome challenges and basic needs.

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Authors' Contribution

M.M: Study design, data analysis, data interpretation, and drafting; M.O: Study design, data analysis, data interpretation, and drafting; M.P: Study design, data analysis, data interpretation, and drafting; A.V: Study design, data analysis, data interpretation, and drafting; All authors read and approved the final manuscript and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work were appropriately investigated and resolved.

Conflict of Interest: None declared.

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