The Impact of Individual and Team-Based Digital Gameplay on Short-Term Memory in the Elderly: A Preventive Approach to Cognitive Decline

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Cognitive decline has been studied extensively for the geriatric population to slow the process, by focusing and improving certain cognitive functions. As we get older, our ability to retain information reduces significantly, leading to a profound impact on a person's health and well-being. This study aims to understand how different learning styles, namely individual and collaborative, as well as digital interventions can enhance short-term memory and attention span for senior citizens. An app was designed that contained five digital games, each of which focused on different types of memory and attention span. The app measured the scores and reaction times of the senior citizen when played individually, or in teams. Additionally, the study followed a quasi-experimental design to analyze the improvement of short-term memory and attention span pre and post-playing digital games for 30 senior citizens. The study explores a notable gap in existing research, as few researchers have explored the use of gamification for senior citizens and even fewer compare the effectiveness of team-based versus individual interventions. The digital game intervention has shown promise as a successful method for engaging senior citizens to enhance their cognitive functions using interactive interventions. Furthermore, the team-based learning style was observed to be more effective in improving their short-term memory and attention span. Further research on this area may help researchers prevent cognitive decline and benefit elderly populations to live more fulfilled lives.

Keywords: digital games, cognitive improvement, memory, older adults, attention span

Introduction

Cognitive decline has been a prominent focus of recent research related to the geriatric population, specifically focusing on memory and attention span. Working memory is defined as a brain system that acts as a short-term store and handles information required for intricate cognitive functions, including language, reasoning, and learning[1]. This concept was examined and observed, to comprehend how short-term memory is stored and retrieved[2]. Similarly, attention span is the length of time and ability to concentrate on a specific activity or subject without getting distracted by surrounding details[3]. As people grow older, reduced cerebral blood flow to the frontal lobe and hippocampus disrupts the functionality of the neuron receptors leading to memory deterioration[4]. Further, ageing individuals lose neurons over time, making it difficult to concentrate. These neurochemical changes lead to longer processing time and lower ability to focus on specific tasks, leading to weaker cognitive responses and faster decline.

Psychologists have tested different strategies to reduce cognitive decline among senior citizens. Researchers examined whether social integration protects against memory loss for senior citizens in the US, concluding that social integration delays memory loss, and thus slows the rate of cognitive decline[5]. Similarly, research by Hee-Lee and colleagues suggested that seniors in Korea participating in clubs, and interacting with adults and children may help reduce cognitive decline and strengthen memory and attention span[6].

Furthermore, numerous technologies have been implemented to improve memory and attention span for the elderly. One such technique was the use of digital games the 'Eagle Eye Challenge' developed by Siricharoen and team, which helped improve short-term memory skills by recalling, comparing and contrasting details from two similar images[7]. Similarly, Rummun and Naowah developed a brain training app called 'Genius' aiming at improving memory, attention, problem-solving, speed, concentration, reflex, communication and language skills for Dementia and Alzheimer's patients above 60[8]. Another such app called 'Peak' created by Carter and colleagues includes features like personalised assessments, progress tracking, and daily challenges, to motivate individuals to stay consistent with their cognitive training[7]. Similarly, research further incorporated the use of engagement within their digital games. For example, Sauvé and Renaud developed 'Live Well, Live Healthy:' an

interactive bingo game, which was used to measure the quality of life of the elderly[9]. This was effectively measured through visual and audio feedback such as smiley and sad faces as well as questionnaires.

Additionally, Al-Thaqib and his team developed 'Luminosity'- an accessible brain training app used by a lot of researchers to measure cognitive abilities. Brain Training Game (BTG) research depicted improvements in executive functions and processing speed in terms of attention span in elderly subjects[10]. With the development and assistance of brain training apps, research suggests it has improved cognitive abilities including improved spatial memory, faster reaction time, and increase in attention as well as improvement in recalling memories.

Existing research has dealt with determining the effect of social integrations, types of social activities and their effect on reducing cognitive decline by strengthening short-term memory and attention span. However, there is still a gap in discovering how playing digital games using different learning styles (individual versus group learning), can enhance short-term memory and attention span. Additionally, the majority of existing clinical research (cited above) in the area of digital games for the elderly, has been through interventions on individuals. There has also been limited research comparing learning styles (individual vs. team-based) highlighting the need for the same. For example, participating in these digital games in teams versus individually could have a difference in improving short-term memory and attention span for senior citizens. Moreover, fewer studies have focused on comparing the impact of this intervention on the Indian population. This study aims to fill this gap by exploring the impact of specifically designed digital memory games on the short-term recall abilities of senior citizens within India.

The study's first hypothesis (H1) suggests that seniors engaging in digital games will exhibit a greater improvement in their short-term memory and attention span, as measured by standardized cognitive tests. The second hypothesis (H2) suggests that participants involved in social learning, as compared to individual learning, will have a better overall performance.

This research aims to fill a few gaps, including contributing to the understanding of how digital cognitive interventions can enhance memory functions in the elderly population. This is important because enhancing cognitive functions in the elderly can significantly improve their quality of life, contribute to their independence, and potentially mitigate the risks of cognitive decline associated with ageing. Additionally, advances in technology have made it easier to track and observe their progress over time using digital analytics. Therefore, this research sought to compare playing digital games in groups or individually, to explore which one is more effective and has larger benefits for the elderly.

Results

Results revealed that all participants who interacted with the digital game intervention had improvements in their short-term memory and attention span when comparing pre-test and post-test results using statistical techniques like t-tests and regression analyses. Moreover, participants who engaged in collaborative gameplay had a greater improvement in these cognitive functions compared to the individual condition. Correlation analyses showed that participant age had a negative correlation to task performance in each digital game.

The following paragraphs will discuss the descriptive statistics for all participants (Table 1), individual conditions (Table 2) and group conditions (Table 3).

As can be noted in Table 1, there were a total of 30 participants (16 in the individual condition and 14 in the group condition). The survey respondents included participants from both genders, ages 60 - 80 years from India. The mean age of respondents was 72 years (n = 30). From this sample, approximately 56.6% of the participants were female and 43.4% were male. Of the total respondents (n = 30), 6.7% of the participants had only a high school diploma, 40.0% had a bachelor's degree and 53.3% had a postgraduate degree as well.

For both conditions and each digital game, the results were normally distributed with all skewness values between -1.441 and 0.952. Similarly, the Kurtosis values ranged between -1.721 and 2.223, suggesting a normal distribution of data.

To summarise - the tables above (tables 2 & 3) presented the average reaction time (in seconds) and total score for each game under both experimental conditions. It was noted that for Game 1 (Salad Shuffle), participants in the individual condition had a lower average reaction time (M = 9.81), and a lower total score (M = 319.38) compared to the group condition. This trend was consistent in Game 1 (Salad Shuffle), Game 4 (Digit Dynasty), and Game 5 (Multitask Mania). In Game 2 (Colour Clash), participants in the group condition had a higher average reaction time (M = 267.94); however, their performance in the game was weaker than in the individual condition (M = 227.65). On the other hand, in Game 3 (Recall Rhapsody), participants in the group condition had a lower average reaction time (Mean = 8.64) and performed better than the individual condition (M = 214.28). Game 5 (Multitask Mania) does not measure reaction time and only calculated values of the total score for participants.

The following tables (Tables 4 and 5) exhibit the differences in the total scores of the participants at the pre-intervention time point and post-test time point for the group and individual conditions.

Given the modality of data collection–physical, in person–only total scores were calculated across all 5 tests. Both the pre-test and post-test were performed individually by all participants in the experiment. There was improvement from pre-test to post-test results for both conditions. In the individual con-

Variable	Individual	Group	Total
Number of Participants	16	14	30
Mean Participant Age	74 years	71 years	72 years
Participant Gender	n = 10 Female n = 6 Male	n = 7 Female n = 7 Male	n = 17 Female n = 13 Male
Education Level	9 Post graduates 6 Bachelor's degree 1 High school	7 Post graduates 6 Bachelor's Degree 1 High School	16 Post graduates 12 Bachelor's Degree 2 High School

Table 1 Descriptive Statistics for All Participants in The Study

	Game 1 Average Reaction Time	Game 1 Total Score	Game 2 Average Reaction Time	Game 2 Total Score	Game 3 Average Reaction Time	Game 3 Total Score	Game 4 Average Reaction Time	Game 4 Total Score	Game 5 Total Score
Valid	14	14	14	14	14	14	14	14	14
Mean	10.586	331.429	267.943	227.657	8.643	214.286	5.3	487.143	271.429
Std. Deviation	2.474	67.807	3.843	28.989	1.61	39.945	1.797	15.407	72.839
Skewness	0.573	-1.441	-1.297	-0.034	-1.31	-0.149	-0.038	-0.914	0.952
Kurtosis	-0.161	1.059	0.559	-0.379	0.511	-1.721	-1.668	-0.751	-1.018
Minimum	7.4	190	260.2	180	5.4	160	2.9	460	210
Maximum	15.1	390	271.6	273.6	10	260	7.8	500	390

Table 2 Descriptive Statistics for Average Reaction Time and Total Score for all games in the Group Condition

	Game 1 Average Reaction Time	Game 1 Total Score	Game 2 Average Reaction Time	Game 2 Total Score	Game 3 Average Reaction Time	Game 3 Total Score	Game 4 Average Reaction Time	Game 4 Total Score	Game 5 Total Score
Valid	16	16	16	16	16	16	16	16	16
Mean	9.819	319.375	267.4	242.5	9.719	187.5	6.506	448.75	237.5
Std. Deviation	3.656	51.571	9.982	51.575	2.601	49.329	2.434	44.253	80.953
Skewness	0.536	-0.346	-1.4	-1.19	0.713	0.533	0.779	-1.424	0.75
Kurtosis	-0.6	-1.353	1.025	0.674	0.709	0.522	-0.119	2.223	-0.096
Minimum	4.6	240	243.2	130	5.7	110	3.8	330	130
Maximum	17.3	390	275.8	300	15.9	300	11.8	500	400

Table 3 Descriptive Statistics for Average Reaction Time and Total Score for all games in the Individual Condition

	Pre-Test Total Score	Post-Test Total Score
Valid	14	14
Mean	79.50	90.50
Std. Deviation	8.93	3.94
Skewness	-0.99	0.04
Kurtosis	1.20	-1.49
Minimum	58	85
Maximum	92	96

Table 4 Descriptive Statistics for Total Scores Across Games for Pre-Test and Post-Test Conditions for Group Condition

	Pre-Test Total Score	Post-Test Total Score
Valid	16	16
Mean	78.13	87.25
Std. Deviation	7.43	4.22
Skewness	-1.4	-1.58
Kurtosis	1.51	2.53
Minimum	60	77
Maximum	86	93

Table 5 Descriptive Statistics for Total Scores Across Games for Pre-Test and Post-Test Conditions for Individual Condition

dition, the mean score increased from 78.13 to 87.25. In the group condition, the mean score increased from 79.50 to 90.50, suggesting that participants in the group condition significantly performed better in the post-test. For total scores, results indicate that there was a minimal difference for the pre-test between both conditions (individual and group). The individual condition had a slightly lower performance. (M = 78.13), while the group condition scored a slightly higher mean (M=79.50).

T-tests allow for comparing the means across the two groups, therefore Tables 6,7 and 8 focus on comparing t-test scores for pre and post-intervention timepoints across individual and group learning conditions.

Independent Samples T-Test			
	t	**df**	**p**
Pre-Test Total Score	0.46	28	0.65
Post-Test Total Score	2.17	28	0.04

Table 6 Independent Samples Pre-Test and Post-Test Scores for Both Conditions

To test H2 (senior citizens participating in the digital games in a group learning style compared to the individual learning style will perform significantly better in their post-test), pre-test and post-test accuracy were tested using independent samples t-tests across the individual and group conditions. There was no significant difference in pre-test scores for the different learning conditions. However, there was a statistically significant difference in post-test scores between groups (t = 2.18 at p ¡ 0.05) suggesting that the type of learning style had a strong effect on the experiment results.

Paired Samples T-Test for Group Condition				
Measure 1	**Measure 2**	**t**	**df**	**p**
Pre-Test Total Score	**Post-Test Total Score**	-6.95	13	<.001

Table 7 Paired Samples T-Test for Group Condition

Similarly, the researcher conducted a paired sample t-test for the group condition. Results indicated a large t-value (t ±6.95) at p¡0.01), indicating statistically significant results for the group condition.

When combining these results with the descriptive statistics in Tables 2 and 3, it can be concluded that the group condition had a much higher increase in pre-post scores of 11 points compared to 9.125 points in the individual condition.

Paired Samples T-Test for Individual Condition				
Measure 1	**Measure 2**	**t**	**df**	**p**
Pre-Test Total Score	Post-Test Total Score	-9.54	15	<.001

Table 8 Paired Samples T-Test for Individual Condition

To test H2 (senior citizens participating in the digital games in a group learning style compared to the individual learning style will perform significantly better in their post-test) a paired sample t-test was conducted for the individual condition alone. The t value, (t = – 9.54 at p¡0.001), suggests a great probability that the difference between pre-test and post-test scores is significant and cannot be attributed to random chance.

Tables 9,10 and 11 expand on the correlation between the age and performance on playing the Digital Games, Pre-Test and Post-Test scores across individual and group condition.

The researcher found a moderately negative correlation between age and the post-test scores of the participants. Older participants had a weaker performance in the post-test. (r = –0.417, Age, p¡0.05) Furthermore, there was a highly positive correlation between post-test scores and pre-test scores. Participants achieved a remarkable increase in post-test scores, compared to the pre-test. (r = 0.850, Pre-test Score, p¡0.05) A negative correlation between age and reaction time was observed however, this was not strong but significant (r = –0.013, Age, p¡ 0.05) Another noticeable positive correlation was observed between faster reaction times and higher total game score. There was no correlation between participant performance in either condition with respect to their education degree.

In order to ensure there were no confounding variables, the researcher built a correlation matrix. A strong positive correlation was observed between pre-test and post-test scores. Participants in the individual condition performance were significantly likely to improve from pre-test to post-test (r = 0.93, Age, p¡0.05). However, there was no substantial correlation observed between participant age and performance in the digital games as well as the pre and post-test.

The researcher observed a strong positive correlation, observing that participants in the group condition significantly performed better in the post-test compared to the pre-test (r = 0.855, Age, p¡0.05) There was no noteworthy effect of age group on participants' performance in the pre-test, post-test as well as each digital game.

Discussion

The research study aimed to investigate the effect of playing digital games on enhancing short-term memory and attention span in senior citizens using different learning styles. This study was done to understand how digital interventions can minimise and reduce cognitive decline among the geriatric population and enhance their cognitive power in terms of short-term memory and attention span. The objective was to observe if changing learning styles and interventions could have a positive impact on their cognition. Hypothesis 1 (H1) explored if participants would have a significant improvement in their post-test performance after interacting with the digital games interface to improve their short-term memory and attention span. The second hypothesis (H2) focused on whether participants in the study would perform better and have better short-term memory and attention span when working in teams versus individually.

Variable		Age	Pre-Test Score	Post-Test Score
1. Age	Pearson's r			
2. Pre-Test Score	Pearson's r	-0.265	–	–
3. Post-Test Score	Pearson's r	-0.417*	0.850***	–
4. Game 1 Average Reaction Time	Pearson's r	-0.013	-0.095	-0.145
5. Game 1 Total Score	Pearson's r	-0.091	0.098	0.181
6. Game 2 Average Reaction Time	Pearson's r	-0.14	0.478**	0.584***
7. Game 2 Total Score	Pearson's r	0.131	0.242	0.093
8. Game 3 Average Reaction Time	Pearson's r	0.073	-0.103	-0.053
9. Game 3 Total Score	Pearson's r	-0.109	0.336	0.461*
10. Game 4 Average Reaction Time	Pearson's r	0.059	-0.227	-0.304
11. Game 4 Total Score	Pearson's r	-0.029	0.323	0.491*
12. Game 5 Total Score	Pearson's r	-0.119	0.147	0.209
*p < 0.05, **p < 0.01, ***p < 0.001				

Table 9 Correlation for All Participants Among Age and Performance on Playing the Digital Games, Pre-Test and Post-Test

This study effectively conducts a comparison between social learning versus individual learning and supports that social learning strengthens cognitive performance in terms of short-term memory and attention span as well as increased interaction with others can create a more inclusive and interactive learning environment5. Digital games such as the Eagle Eye challenge showed improved short-term memory skills by including recalling practices7. Similarly, in this research, digital game interfaces included three types of memory games that focused on recalling images, words and numbers to holistically improve short-term memory skills for senior citizens.

Based on the pre-post analysis, it was found that the digital game interface had a positive impact on improving short-term memory and attention span for senior citizens. In the within-group design, promising and significant improvements were seen in the scores of the participants (across 5 games) post the intervention. In the between-group conditions, the participants who performed in teams had a better post-test performance score, suggesting that group learning is more beneficial to enhancing short-term memory and attention span than individual learning. Furthermore, specific games had a greater impact on post-test performance. For example, the Stroop test digital game intervention encouraged participants and led to better average reaction time in the post-test. Similarly, after playing game 4 (Digit Span test), participants had an improved score in their post-test performance. Gender can have an influence on cognitive abilities as research suggests that men and women differ in cognitive domains including spatial and verbal memory which could have affected how they engaged with the digital games. However, based on the results of the regression analysis, participants' gender as well as education level had no impact on their performance.

An unexpected finding included weaker participants' performance after each game. This may be fatigue owing to the length of the workshop sessions. Another surprising result of this study was that age did not have a significant effect on participants' performance in the pre-test and post-test. All senior citizens, whether between ages 60-65 or above 80 performed similarly in the game intervention as well as the post-test. According to Fan Zhang and researchers, the meta-regression analysis in their research suggested that for various cognitive functions younger older adults might perform better. However, this relationship was not definitive nor statistically significant, indicating that age alone doesn't determine cognitive game performance[11].

In terms of strengths, the intervention and design of each game represented an inventive approach, as originally developed by the researcher. While creating the games, the researcher ensured the implementation of all relevant metrics based on the different memory and attention span tests. Other apps such as Luminosity focus primarily on one type of memory test and

Variable		Age	Pre-Test Score	Post-Test Score
1. Age	Pearson's r	–	–	–
2. Pre-Test Score	Pearson's r	-0.442	–	–
3. Post-Test Score	Pearson's r	-0.362	0.931***	–
4. Game 1 Average Reaction Time	Pearson's r	0.174	-0.277	-0.307
5. Game 1 Total Score	Pearson's r	-0.284	0.277	0.332
6. Game 2 Average Reaction Time	Pearson's r	-0.076	0.730**	0.797***
7. Game 2 Total Score	Pearson's r	0.098	0.394	0.300
8. Game 3 Average Reaction Time	Pearson's r	-0.045	-0.193	-0.051
9. Game 3 Total Score	Pearson's r	-0.146	0.492	0.532*
10. Game 4 Average Reaction Time	Pearson's r	-0.211	-0.388	-0.396
11. Game 4 Total Score	Pearson's r	-0.296	0.398	0.455
12. Game 5 Total Score	Pearson's r	-0.241	0.402	0.367
*p < 0.05, **p < 0.01, ***p < 0.001				

Table 10 Correlation Among Age and Performance on Playing the Digital Games, Pre-Test and Post-Test for the Individual Condition

improving this cognitive skill through that game. The inclusion and exclusion criteria were strictly maintained to decrease any variability within the participant sample as well as minimize confounding variables, strengthening the internal validity. Alongside this, the criteria make it easier to replicate the study.

Nonetheless, there are certain limitations to the study. The study had a relatively small sample size with only 30 participants. There was an uneven proportion of participants in the two conditions as well as an uneven number of male and female participants, which could have resulted in misleading effect sizes, affecting the generalisability of the sample. Secondly, the participants were all Indian citizens and from wealthy households. This limits the generalisability of the study as it doesn't include the diversity present in a larger population. Additionally, the pre-test and post-test data were collected physically, whereas the intervention data was collected online. This methodological constraint made it difficult to distinguish between practice effects. The study did not test on a control group, thus, the researcher couldn't accurately observe if the results were due to practice effects or the game intervention itself, leading to low validity of the research results. These raise concerns regarding the reliability, which can be addressed with further research with a larger sample size.

Implication and Future Research Direction

The findings of the study suggest broader implications of digital games beyond cognitive improvements, including emotional well-being, socialisation and improved quality of life for seniors. Collaborative environments that foster social interaction help reduce feelings of isolation and enrich engagement. This study allowed the researcher to explore two subjects to create an interdisciplinary medium between Computer Science and Psychology and comprehend the integration between these subjects. This research could potentially help caregivers and doctors focusing on the geriatric population to reduce the rate of cognitive decline as people age and enrich one's cognitive functions consistently over the long term.

Future research with this game intervention includes studying long-term memory and its effect on reducing cognitive decline in the long term as well as understanding the longitudinal effects of short-term memory itself. The researcher also aims to test the study across different generations and age groups to determine the effect of these learning styles and digital game intervention on children and adults as well. Moreover, exploring the impact of digital versus physical game interventions is another aspect that the researcher could further explore to expand their understanding of the topic. Digital games can also be utilized to improve long-term memory as well as other cognitive functions

Variable		Age	Pre-Test Score	Post-Test Score
1. Age	Pearson's r	–	–	–
2. Pre-Test Score	Pearson's r	-0.115	–	–
3. Post-Test Score	Pearson's r	0.312	0.855***	–
4. Game 1 Average Reaction Time	Pearson's r	-0.145	0.125	-0.039
5. Game 1 Total Score	Pearson's r	0.088	-0.047	-0.009
6. Game 2 Average Reaction Time	Pearson's r	-0.345	0.076	0.226
7. Game 2 Total Score	Pearson's r	0.060	0.085	-0.081
8. Game 3 Average Reaction Time	Pearson's r	0.033	0.073	0.239
9. Game 3 Total Score	Pearson's r	0.133	0.142	0.191
10. Game 4 Average Reaction Time	Pearson's r	0.159	0.003	0.060
11. Game 4 Total Score	Pearson's r	0.000	0.313	0.241
12. Game 5 Total Score	Pearson's r	0.137	-0.155	-0.174
*p $<$ 0.05, **p $<$ 0.01, ***p $<$ 0.001				

Table 11 Correlation Among Age and Performance on Playing the Digital Games, Pre-Test and Post-Test for the Group Condition

for the geriatric population. Future research could also include a larger sample size to improve the generalisability of the results attained as well as focus on understanding and strengthening new memory interventions.

Methodology

Participants

The participant sample included only senior citizens, both males and females above the age of 60. In accordance with the National Policy of Senior Citizens in India, individuals above the age of 60 are legally considered senior citizens. The study used a convenience sampling method with participants recruited through WhatsApp broadcast messages between April 20th and May 2nd, 2024, resulting in a small, non-representative sample of 30 elderly individuals from wealthy households in India. Due to health-related concerns with a few participants, unequal sample sizes were found for individual and group conditions (16 and 14, respectively).

The inclusion criteria for the study state that all participants came from cultural backgrounds within India, spoke Hindi and English and had middle-to-high-class incomes. Participants had education levels ranging from high school degrees to PhDs. Familiarity and ease in operating mobile phones, with touch screen functionality was a requirement in order for participants to take part in the study. The exclusion criteria required participants to indicate any pre-existing neurological conditions, through a self-report measure (survey form).

Materials and Methods

Brainstorming and Game Design

Since the primary focus was short-term memory and attention span, the researcher focused on Phonological, Visual and Spatial short-term memory skills as well as Selected and Divided attention span. There were five focal tests based on those skills: Visual memory span test, Stroop test, Pattern recall test, Digit span test and Dual-task design. While keeping these in mind, the research developed five digital games that are built around these tests in an entertaining, game-like design using Miro boards.

The first game was called Salad Shuffle. The game focused on Visual Short-term memory. In this game, participants were shown salads and different positions on the screen for a few seconds. Once they disappeared, participants were asked to click on the location where the salads were previously shown. This game had 7 levels total with the grid size increasing to show more salads as the levels increased. Level 1 started off with 3 salads and increased up to 9 with one salad extra added in each level. In the first level, participants were shown the salad

for 10 seconds which decreased by one-second increments each level to the end.

The second game was known as Colour Clash. This assessed the participants' reaction time and selective attention span to interpret the right colours as quickly as they could. This game involved showing participants words of different colours. The task was to name the colour of the ink in which the word is written, rather than the word itself. This was challenging, however, it measured their ability to suppress a habitual response in favour of a less dominant one while improving their reaction time. This game consisted of 6 levels. In each level, there were 6 of these Stroop tests which showed the colour word as well as two multiple-choice options to select the correct answer of the ink. Nonetheless, these appeared at different time intervals in each level. In level 1, there was a 6-second gap between each multiple-choice question, which decreased to 1 second between each for the 6th level.

The third game, known as Recall Rapsody, assesses spatial short-term memory principles. This game has an 18-box grid in black. Some of these grid boxes flashed in red for 2 seconds and disappeared. Participants had to reselect the correct grid boxes that flashed red in the correct order as well. This game included 10 levels in total and the number of red grids flashed increased by one every level.

The fourth game was Digit Dynasty. This game assessed the Phonological Short-term memory principle using the digit span test. A series of digits were presented on the screen for a set amount of seconds and were removed. Participants had to use the keypad on the app screen to retype the digits shown in the correct order. This game included 10 levels with the number of digits starting at 3 and increasing up to 7 by the final level. The number of digits introduced was increased by one after every two levels.

The final game, Multitask Mania was a game that required participants to complete two tasks simultaneously to assess their divided attention span. Dual-task processing is to measure the concurrent performance of different tasks to evaluate a person's ability to multitask. Participants are asked to perform two tasks simultaneously. In this research, the two tasks were image classification and basic arithmetic. The first task asked participants to select the correct vegetable picture from the given options based on what was asked. The second task asked participants a basic addition math question and they were asked to select the right answer from the multiple-choice options presented. Participants were given 2 minutes in total to answer as many questions as they could for both tasks and observe their collective performance to evaluate their ability to multitask.

The backend of each game was programmed by the researcher using Thunkable and published through a web app. This tool required less heavy coding, and instead utilized block coding techniques. The data for the digital games was collected from the app using Firebase. This ensured secure data as well as maintained information anonymously to establish a double-blind experiment. Participants were required to sign in to the app in order to play the digital games to guarantee their data was saved in the Firebase. The app was programmed to measure both the accuracy and reaction time of the participants for each of the five games. Furthermore, Canva was a prominent tool in creating the aesthetics and front end of the app to improve user-interface design. To analyse the results, an independent and paired sample t-test was used to compare the score and reaction time between the two groups. Additionally, regression models were used to assess the correlation between all variables.

Experimental Design

Additionally, no time constraints were imposed. Participants could progress through each level of every game at their own pace. This study followed a quasi-experimental design exploring a cause-and-effect relationship. The independent variable was learning style (individual versus group) and the dependent variable measured the total scores and average reaction time per game. The results were collected through the pre-test and post-test to calculate their short-term memory and attention span by measuring their accuracy and reaction time to support or reject the hypotheses. All participants played 5 digital games: Salad Shuffle, Colour Clash, Recall Rapsody, Digit Dynasty, and Mustitask Mania. This design allows the researcher to measure the change in participants' performance by controlling individual differences to reduce variability and observe the intervention effects. Participants in the individual condition played the digital games on their own mobile phones independently. However, in the group condition, participants were divided into groups of two and shared one mobile phone to play the digital games together while communicating.

Procedure

Pre-test and Post-test

The pre and post-tests were designed by the researcher to evaluate short-term memory and attention span skills. For each test, there were found rounds/levels that increased in the level of difficulty. The tests measured the precision of the participant's answers and tabulated the data in a Microsoft Excel spreadsheet to calculate the total score for all five tests. During the pre-test, the researcher also collected certain demographic data about the participants such as age, gender, education level, and familiarity with digital games. Participants were informed that the pre and post-test were practice games to eliminate any fear of testing that could affect their performance. Before the experiment, all participants were asked for consent, SRC approval was taken to conduct data collection to ensure the experiment remained ethical. Additionally, all data that was gathered has been kept confidential and anonymous.

Gameplay

The researcher created a web application that was circulated to senior citizens by sharing the link through WhatsApp. The link was generated from Thunkable which could be accessed by anyone on their mobile phone to play the digital games. To gain primary observation as well as data collection through the database, the researcher directed workshops with senior citizens. Participants were asked for consent and requested to sign consent forms and were entirely debriefed about the experiment's aims before the study procedure began. Participants were randomly assigned to either of the two conditions: Individual and Group by drawing a chit. A repeated measures design was followed as all participants took part in the pre-test and post-test. There was a disparity in the sample size due to attrition. Participants in the individual condition had to participate in both pre-tests and post-tests as well as play the digital games on their own. In the group condition, participants were required to do both pre and post-tests alone; however, they played the digital games in teams of two by sharing one mobile phone. During the experiment: participants did the pre-test, played the digital games, took a break and completed the post-test.. For the digital games, participants watched demo videos on the app for each game to understand the gameplay rules. The researcher was also present to answer any questions and provide any additional assistance and description.

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