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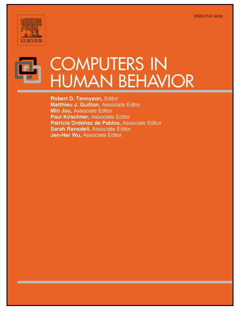

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CRediT Statement

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Short Video Game Play Improves Executive Function in the Oldest Old

Living in Residential Care

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Abstract

Action video game play as a form of cognitive training shows promise, but has not been widely tested with participants exclusively over age 80 years. Age-related decline in executive function produces widely varying levels of ability to function independently. This study aimed to examine the change in executive functioning after a 3-week action video game intervention in healthy adults aged 80-97 years living in residential care. Participants were randomly assigned to either an experimental or care-as-usual control group: experimental participants played *Star Wars Battlefront*©, a commercially available video game, for six supervised sessions of 30 minutes each. Participants completed neuropsychological and quality of life assessments pre-training, post-training, and one month later. The experimental group showed significant improvement in the visual attention and task switching domains, in both post-test and follow-up sessions. Working memory also improved in the experimental group; however, after one month of no game play, memory performance regressed toward baseline levels. Results support the incorporation of video game play as a leisure option for older adults, which may also play a role in enhancing cognitive health. The findings extend previous research conducted below age 80 years to the oldest-old, an age group in which longitudinal follow up data is limited.

Keywords: Video Games; Elderly; Executive Function; Visual Attention; Task Switching; Residential Aged Care

Highlights

- Short video game play influences executive function in oldest-old
- Participants aged 80-97 years were cognitively healthy, living in residential care
- Experimental group played an action video game with pre, post and follow-up tests
- Visual attention and task switching improved and persisted at follow-up
- Working memory improved after game play but regressed toward baseline at follow-up

1. Introduction

Globally, life expectancy is increasing, yet as age increases, cognitive abilities decline (Murman, 2015; United Nations, 2017), with advancing age identified as a primary risk factor for neurodegeneration (Salthouse, 2010). Even individuals with only moderately impaired cognitive abilities lose the capacity to live independently. Loss of independence is recognized widely as contributing to the deteriorating quality of life in the elderly (Williams & Kemper, 2010). As such, finding ways to prevent or mitigate the cognitive deterioration associated with aging, is of extreme importance to not just older adults, but also to their carers and society in general.

The most rapidly growing age group in the general population is those over age 65, with the oldest-old subgroup over age 80 forecast to triple worldwide by 2050 (He, Goodkind, & Kowal, 2016). Such growth in this at-risk population has been identified as a critical driver to develop effective methods for the elderly to preserve their independence and quality of life (Australian Productivity Commission, 2015). For such methods to be truly effective, they should be enjoyable and easy to access. As a consequence, the playing of video games has been identified as one possible way of improving the independence and quality of life of aged populations generally, and residents in aged care, specifically (Keogh, Power, Wooller, Lucas, & Whatman, 2014).

Video game play is easily accessible and has been the subject of various socioemotional studies (Allaire et al., 2013) as well as numerous studies of its impact on cognition in older adults, focusing on game play as a method of cognitive training (Anguera et al., 2013; Sosa & Lagana, 2019; Toril, Reales, & Ballesteros, 2014). Cognitive ability, the capacity to perform mental processes associated with problem-solving and learning, is an essential component of independent living (Hunter, 1986). Within cognitive ability, executive function drives the capacity to plan and carry out action, inhibit inappropriate action or thought, organize thoughts, and encode and retrieve information (Diamond, 2013). Aspects of executive function include working memory, task switching or cognitive flexibility, attention, inhibition, and processing speed (García-Madruga, Gómez-Veiga, & Vila, 2016). The possibility of enhancing executive function through intervention has been a focus of studies investigating single or multiple processes, with working memory, task switching, and attention a recurring combination (Anguera & Gazzaley, 2015).

The scaffolding theory of aging and cognition (STAC) was developed as an attempt to explain differing levels of neuroplasticity in older adults. This theory included four compensatory measures: neural engagement, new learning, physical exercise, and cognitive training (Reuter-Lorenz & Park, 2014). Neural engagement is autonomic and not consciously manipulated (Park & Bischof, 2013); new learning and physical exercise have been studied extensively, with results supporting lifestyle changes and public acceptance growing as literature expands (Williams & Kemper, 2010). Cognitive training involves external interventions designed to enhance mental abilities, exercising the brain versus the body (Lustig, Shah, Seidler, & Reuter-Lorenz, 2009), and has seen less decisive acceptance, with the concept of cognitive enhancement still seen by many as controversial (van Heugten, Ponds, & Kessels, 2016).

A growing body of research does, however, indicate that executive function can be improved through computerized training (Khosravi & Ghapanchi, 2016; Kueider, Parisi, Gross, & Rebok, 2012). Comparison of a wide range of computerized cognitive training interventions in the elderly using puzzles, educational software, or video games showed small but significant cognitive improvements (g = .22; Lampit, Hallock, & Valenzuela, 2014). Studies have further suggested that game play with obvious short-term improvements can also lead to improved functionality in real-world situations through the process of *perceived transfer effect* (Talaei-Khoei & Daniel, 2018); for example, improvements in driving simulator game scores are correlated with improvements in actual driving ability. It has even been suggested that performance on some educational brain training games may be a cost-effective, risk-avoidant means of assessing driving capabilities in the elderly (Vichitvanichphong, Talaei-Khoei, Kerr, Hossein Ghapanchi, & Scott-Parker, 2016). In all types of gaming, however, the primary challenge is adherence; cognitive training must be appealing in order to be sustained. Researchers likened the comparison between educational brain training software and video games designed for entertainment, to the difference between treadmill exercise versus running down a field during a sports match (Anguera & Gazzaley, 2015). If cognitive benefits can accrue from a source of entertainment, older adults may be motivated to train regularly (Ferguson, Nielsen, & Maguire, 2017).

As research into the cognitive effects of gaming has expanded, the industry has also grown. Globally, video game spending currently triples spending on movie tickets and may surpass professional sports expenditure by 2022 (Wijman, 2018), while a 2019 study reported that of 3,228 Australians surveyed, 42% over age 65 play video games (Brand, Todhunter, Jervis, & Wilson, 2019). Of these, 73% reported playing games to “keep the mind active", while 57% simply reported “to have fun” while, overall, 87% of respondents thought game play beneficial to increasing their mental stimulation, and 81% thought it helped to protect against the development of dementia (Brand et al., 2019). By comparison, a 2018 UK survey of video game players in all age groups reported that 25% were over 56 years of age (UK Interactive Entertainment Association, 2018), while data collected by Pew Research in 2017 indicated that 24% of all players in the United States were over 65 years of age (WEPc, 2019).

From a cognitive training perspective, video games have been empirically studied since the 1980s when Drew and Waters (1986) found that older adults' processing speed improved with Atari® game play. Similarly, Goldstein et al. (1997) found reaction time improved in elderly participants after playing a computerized puzzle game. Research across age groups has since expanded, including the development of game-like cognitive research interface (CRI) instruments ranging from *Space Fortress* in 1983 to *NeuroRacer* in 2013 (Anguera & Gazzaley, 2015)**,** with a 2019 systematic review of 17 gerontological gaming studies (Sood et al., 2019) finding that 12 reported improvements in at least one cognitive function such as attention or executive function in patients with dementia or mild cognitive impairment.

In order to better understand the differences between the many different video games available, a systematic literature review was conducted, yielding 764 sources. A staged review was then executed to exclude non-experimental comparative and correlational studies, as well as any study which did not include a targeted video game intervention. Additional exclusions included age groups below 60 and any study which did not include measurement of executive function. Finally, the testing instruments were considered; only studies using neuropsychological tests were included, removing studies that solely utilized neuroimaging data such as EEG or fMRI results.

Review of this literature revealed that not all video games are equal, nor do they equally influence cognition. Many game genres exist including strategy, driving, adventure, role-playing, puzzle, sports, and "exergames," wherein play requires physical exercise. Different genres contain widely varying elements that stimulate the player's cognition in different ways and produce variable effects (Pallavicini, Ferrari, & Mantovani, 2018). Studies of the impact of all video game genres on cognition equated the breadth of the term “video game” to that of “food” (Green, Fiske, & Seitz, 2015) or categorized the term as superordinate, suggesting that video games must be divided into categories in order to effectively measure their cognitive impacts (Bediou et al., 2018). Of the game genres studied, empirical evidence points to the action video game genre as providing the most consistent positive influence on cognition (Bavelier, Bediou, & Green, 2018; Chandra, Sharma, Salam, Jha, & Mittal, 2016; Dobrowolski, Hanusz, Sobczyk, Skorko, & Wiatrow, 2015; Dye, Green, & Bavelier, 2009; Strobach, Frensch, & Schubert, 2012). Further, gaming equipment is an important factor. Some studies using exergame consoles such as the Nintendo Wii or Xbox Kinect found that this genre was primarily useful for physical outcomes such as falls prevention in the target population (Marston, Freeman, Bishop, & Beech, 2016; Howes, Charles, Marley, Pedlow, & McDonough, 2017). However, it has also been suggested that using exergames to measure cognitive function risks a confound when assessing whether cognitive benefit accrued from challenges to executive function or the physical exercise required to operate the console (Sala, Tatlidil & Gobet, 2018).

Commercial brain training games are often grouped with action games and can influence cognition (Kueider et al., 2012; Lampit et al., 2014; Toril et al., 2014). However, these products involve reading, mathematics, and puzzle exercises, and do not meet any action criteria as defined by the literature (Bediou et al., 2018; Green et al., 2015). It has even been argued that brain training products should not legitimately be categorized as video games but rather gamified cognitive tests (Belchior et al., 2016).

Inconsistent genre definitions and groupings may have confounded the results in previous meta-analyses, which failed to find that gaming yielded significant effects on cognitive ability (Sala et al., 2018). To address disagreement within the field, Bediou et al.

(2018) developed a neuropsychological definition for action games used in cognitive training: 1) fast, non-linear pace requiring immediate motor response; 2) intense perceptual load requiring planning, establishing objectives, and use of working memory; 3) rapid switching between wide and narrow focus and 4) distractors with irrelevant information to be suppressed. They argued that, based on this definition, several games showing positive cognitive effect in previous studies could not legitimately be categorized as action games for lack of speed and non-linear composition.

As with any compensatory activity, games must be easy to access and learn (Hwang, Hong, Hao, & Jong, 2011). Arguably this excludes CRI games developed by neuroscientists that are not easily accessible to the public (Bediou et al., 2018). Commercial video games have the advantage of broad appeal given their design for entertainment and advertising visibility. However, some commercial action games used previously, such as *Medal of Honor* or *Call of Duty*, contain potentially objectionable content, including realistic violence and offensive language (Colzato, van den Wildenberg, Zmigrod, & Hommel, 2013). A study of video game enjoyment indicated such characteristics might be offensive to older adults (Ferguson et al., 2017). A positive correlation between increasing age and effect size from video game play was discovered through the use of age as a moderator variable, separating participants aged 60-70 years from those 71-80. Toril et al. (2014) suggested this trajectory might continue in older age groups but did not isolate those over age 80 years, revealing an opportunity to study gaming effects in the oldest-old.

Further research echoed the paucity of game study in the oldest-old and advocated further exploration of this group in exclusivity (Marston et al., 2016; Vaportzis, Niechcial & Gow, 2019), a complaint echoed in the most recent meta-analysis reviewed which covered ages 60-82 years (Mansor, Chow & Halaki, 2019). Studies of medical and cognitive outcomes in elderly populations advocate studying the young-old (65-79 years) and oldest-old 80+ years, separately (Fries et al., 2000; Lee, Oh, Park, Choi, & Wee, 2018); it is proposed that existing video game research can be extended by studying ages 80 years and above in isolation. Further, there is a general dearth of longitudinal follow-up in studies involving the oldest-old (Davies et al., 2014), revealing an opportunity to extend the literature by introducing a longitudinal element. A meta-analysis of brain training interventions in seniors revealed successful retention of attentional control after a one-month period (Buitenweg, Murre, & Ridderinkhof, 2012), suggesting a one-month follow-up period could be appropriate in the age group of interest. Most studies involved community-dwelling participants; the few existing studies in residential aged care utilized exergames, which prioritize physical outcomes (Howes et al., 2017). Furthermore, the finding that shorter training seems to yield larger effects (Toril et al., 2014; Wang et al., 2016) suggests investigation to identify the briefest training period possible to yield significant results.

Given the lack of research into the effects of gaming on the oldest-old, the present study sought to investigate whether *action* video game training using a commercially available game may have a positive influence on multiple domains of executive function in cognitively healthy adults aged 80-99 in residential care. Based on previous research (Anguera & Gazzaley, 2015; Belchior et al., 2013; Stern et al., 2011) it was hypothesized that performance on measures of visual attention, task switching, and working memory would improve in a group of participants engaging in video game play compared to those that did not play. It was further hypothesized, based on Buitenweg et al. (2012), that such gains would be maintained one month after game play ceased. Finally, based on the premise of a perceived transfer effect (Talaei-Khoei & Daniel, 2018) it was predicted that the group engaging in game play would score higher on a measure of quality of life (QoL) following training than the non-playing group; that is, given the residential care environment, perceived improvements in cognitive abilities would transfer to perceived improvements in QoL.

2. Material and Methods

2.1. Participants

A preliminary power analysis indicated an effect size of .25 and a power level of .90 could be reached with 24 participants (Faul, Erdfelder, Buchner, & Lang, 2009), similar to previously published studies (Belchior et al., 2013; Strenziok et al., 2014). Of a sampling frame of 110 individuals in two residential aged care facilities under the same ownership, 63 residents were invited by an independent third party after pre-qualification by age and annual cognitive assessment. Twenty-nine volunteered and gave signed informed consent to participate. They were then screened using Folstein's Mini-Mental State Examination (MMSE), a measure of cognitive function with a maximum score of 30 (Folstein, Folstein, & McHugh, 1975). The inclusion threshold was 24; lower scores can indicate cognitive impairment (Strauss, Sherman, & Spreen, 2006). MMSE test-retest reliability is .80-.95 with medium construct validity (Clark et al., 1999) and has been used in the target population for video game research (Boot et al., 2013; Strenziok et al., 2014). Participant scores ranged from 24-30 (M = 27.33, SD = 1.86), slightly above normative data for Australian adults aged 62-95 years in assisted living (M = 26.50, SD = 2.82) (Anstey, Matters, Brown, & Lord, 2000).

Following screening, 26 participants matched by sex and age were assigned to the experimental or control group in a randomized block design, ensuring similar proportions of men and women, age, and representation from both facilities in each group. One participant withdrew between orientation and training. Another participant made involvement contingent on control group assignment and was excluded for self-selection, leaving two groups of twelve including 19 women (79%) and 5 men (21%) aged 80-97 years (M = 89.17, SD = 4.01), slightly above the Australian residential aged care average of 67% female (Australian Institute of Health and Welfare, 2018). Participants were Caucasian and spoke English, with an average of 11.67 (3.24) years formal education, sufficient visuomotor acuity and little or no prior video game experience. Two-tailed Bonferroni adjusted t-tests compared the mean MMSE, years of education and age between groups, and also between facilities to assess environmental variance. No significant differences were found. Participant details are summarized in Table 1.

Table 1

Demographic Data for Experimental and Control Participants

	Experimental (*n* = 12)		Control (*n* = 12)	
Sex	Male	Female	Male	Female
	2	10	3	9
	M	*SD*	*M*	*SD*
Age	89.50 years	3.61	89.00 years	4.51
Years of Education	12.25	2.59	11.08	3.68
MMSE	27.08	2.36	27.58	1.11

Note. MMSE = Mini Mental State Examination score.

This research protocol was approved by the University of New England Human Research Ethics committee (HE18-083).

2.2. Measures

Three neuropsychological instruments and one quality of life questionnaire were used as dependent measures. Trail Making Test A/B (TMT) measured visual attention and task switching (Reitan & Wolfson, 1993). TMT is a two-part test: for older adults, Part A has good construct validity as a measure of visual attention, while Part B is a highly valid measure of task-switching ability (Sanchez-Cubillo et al., 2009).

Working memory was measured with two Wechsler Memory Scale-III subscales (Wechsler, 1997): Digit Span (DS) and Letter-Number Sequencing (LNS). DS has high construct validity (Larrabee, Kane, & Schuck, 1983) with a high generalizability coefficient (.80 - .89). Although DS can be reported as a composite score, both normative data and previous video game studies in the population support separate analysis of forward and backward scores (Nouchi et al., 2012). LNS shows minimal practice effects over a 2-12 week period ($d < .15$), and is a valid measure of working memory with high internal consistency ($\alpha = .80$-.89) (Strauss et al., 2006).

Quality of life was measured using the Older Person's Quality of Life (OPQoL-Brief) (Bowling et al., 2013), with 11 questions, e.g., "I have social or leisure activities I enjoy doing" and responses on a 5-point Likert scale. It has high construct validity and concurrent validity with other quality of life measures such as CASP-19 and WHOQOL-OLD (Bowling & Stenner, 2011).

2.3 Apparatus

Game condition equipment included a Sony PlayStation® 4 (model CUH-1202B), and Sony Dualshock™ wireless controller, model CUH-ZCT1E. Devices were connected via HDMI cabling and Bluetooth® signal to televisions in each participant's room at the facility. Monitor size varied from 26-40 inches ($M = 31.50$ inches, $SD = 3.27$); participants sat a mean distance of 185.42 cm (24.00) from the screen.

Star Wars Battlefront© is an action video game where players engage in shooting battles against characters from *Star Wars* films (Electronic Arts, 2015). The game meets neuropsychological requirements for the action genre and does not contain realistic violence or offensive language. Accommodations for novice players include a "survival mission" category with short, single-player games at "normal" difficulty. For consistency, game play was isolated to the mission *Survival on Tatooine*, which consists of 15 “waves” or rounds, where the player is required to defeat enemies in order to progress.

2.4. Procedure

Experimental and control participants were assessed three times using each neuropsychological and quality of life measure. Pre-testing occurred during the week before the game intervention was introduced. Post-testing was administered within one week of the final game session. A follow-up test was conducted for all participants one month later.

The experimental condition included one 15-minute orientation wherein participants watched a researcher model successful play for five minutes. Subsequently, they were guided to hold the controller, then briefly play one wave of the game. All sessions were supervised and conducted according to a manualized protocol. Following orientation, training consisted of six 30-minute gaming sessions conducted over three weeks, totaling three hours of play. The control group received care-as-usual within the residential aged care facility, including clinical care and the opportunity to attend regularly programmed activities such as concerts and film screenings. They did not receive the video game intervention.

Sessions began with reminders about the controller, objective, and order of play. Participants paused if needed for encouragement or troubleshooting until they were able to play successfully. Participants’ time-of-day preference determined the scheduling of sessions; game play took place at approximately the same time of day to control for fatigue effects.

2.5. Data Analysis

A 2x3 mixed model, repeated measures ANOVA in IBM SPSS, version 25 (IBM Corporation, 2017) was used with Bonferroni adjustment to analyze results of tests administered before (T1), immediately after (T2) and one month following the intervention (T3). Post-hoc analysis showed that the power to detect effects was .91.

3. Results

The hypothesis that performance on measures of visual attention, task switching, and working memory would improve in the group of older adults receiving video game training was supported. The hypothesis that gains would persist one month after training ceased was partially supported. The final hypothesis that the experimental group would report improved quality of life following training compared to the control group was not supported. Effect sizes are reported as partial eta-squared (η^2_p) and evaluated against the following benchmarks: S = .01, M = .06, L = .14 (Cohen, 1988), with means visually represented in graphs as a function of training and time for the experimental group and time only for the control group.

3.1 Visual Attention

Changes in the scores on the Trail Making Test A (TMT-A) across sessions are plotted in Figure 1 as a function of pre and post-tests for both groups. Video game play had a significant main effect on time ($F(2, 44) = 4.61$, $p = .015$, $\eta^2_p = .17$); however, the effect of group on TMT-A performance was not significant ($F(1, 22) = 0.01$, $p = .929$, $\eta^2_p < .001$). A significant interaction between time and group ($F(2, 44) = 4.76$, $p = .013$, $\eta^2_p = .18$), indicated improved performance over time by the experimental group, which was not only sustained one month later but continued to improve. Examination of the means showed the experimental group improved by a reduction of 23 s at T2, and by a further 10 s at T3. By contrast, the control group’s performance deteriorated by 21s at T2, then reverted to just under baseline with an improvement of 26s at T3. Pairwise comparisons showed significance from T1 to T3 ($p = .025$).

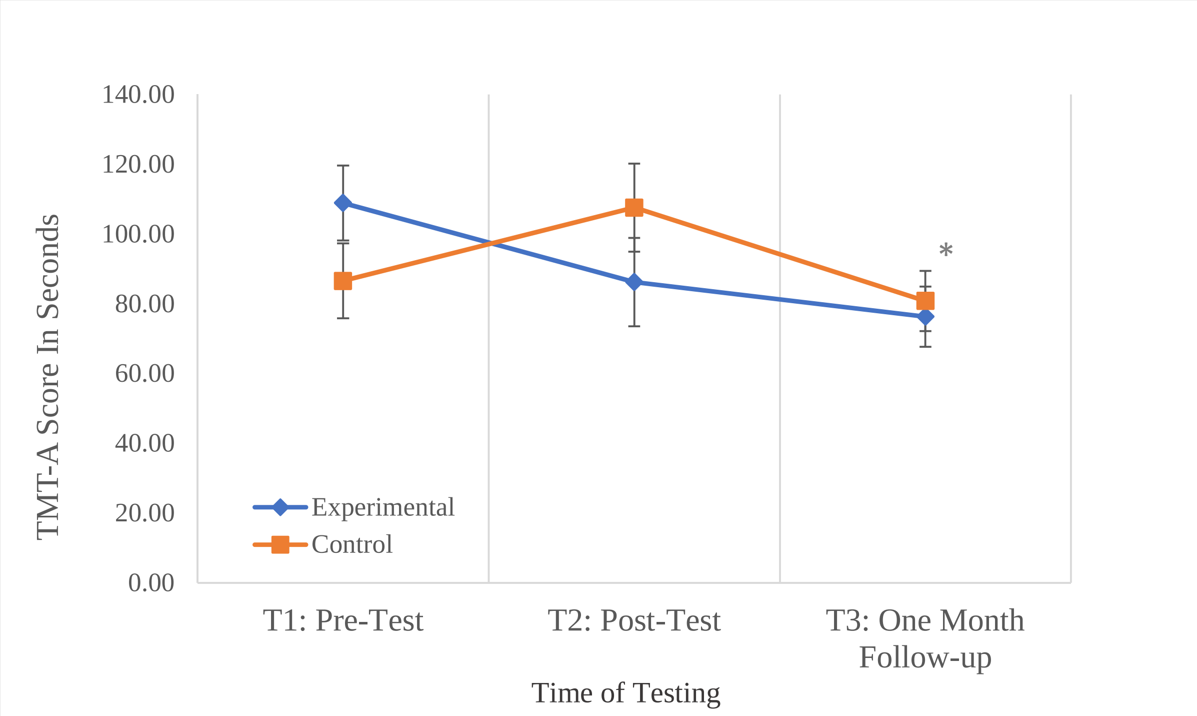

Figure 1. TMT-A mean scores in seconds plotted as a function of time of testing. An asterisk indicates the significant pairwise comparison at T3. The error bars are the standard error of the mean.

3.2 Task Switching

Figure 2 shows the change in scores on Trail Making Test B (TMT-B), as a function of pre and post-testing for both groups. A significant main effect was found for time (F(2, 44) = 4.93, p = .012, η^2_p = .18). The effect of group on score improvement was not significant (F(1, 22) = 1.14, p = .298, η^2_p = .05). A significant interaction for time and group was obtained, (F(2, 44) = 4.54, p = .016, η^2_p = .17). Examination of the means indicated the experimental group improved by a reduction of 50s at T2, sustained their gains and continued to progress one month later with a further reduction by 17s at T3. The control group deteriorated by 7s at T2, then improved by 12s at T3 to finish slightly improved upon baseline. Pairwise comparisons revealed a significant change in test scores between T1 and T3 (p = .036).

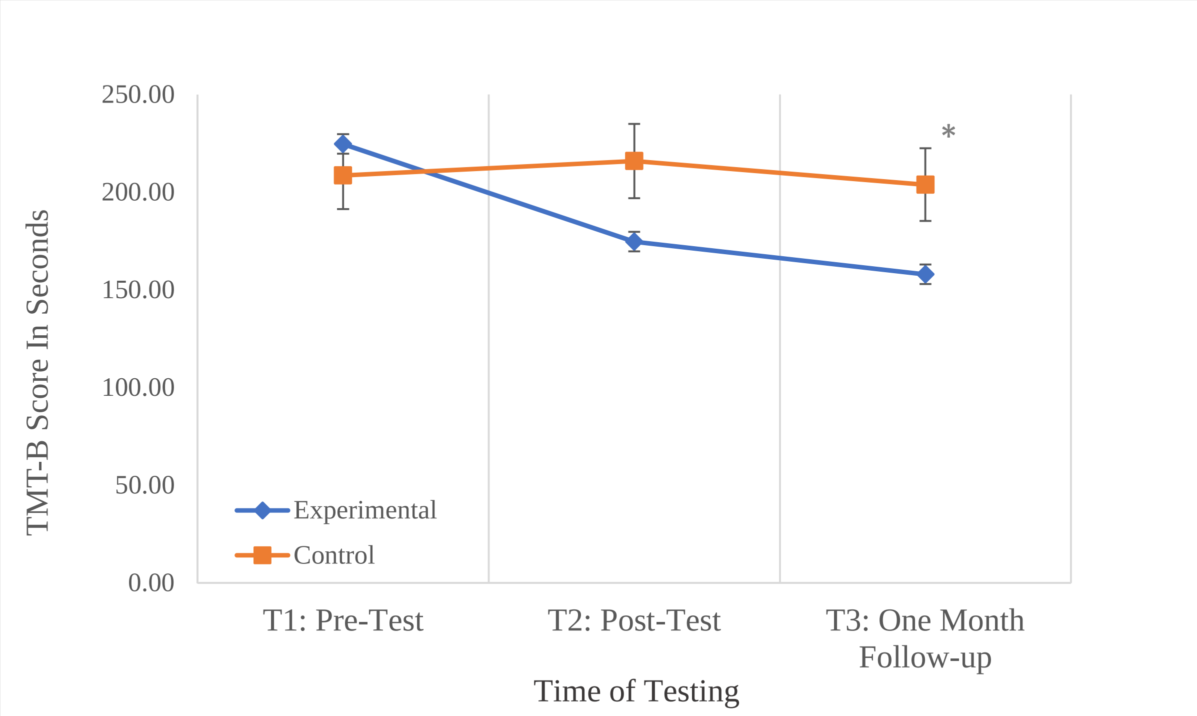

Figure 2. TMT-B mean scores in seconds plotted as a function of time of testing. The significant pairwise comparison is marked with an asterisk at T3 at p <.05. The error bars are the standard error of the mean.

3.3. Working Memory

Of the three measures used to assess working memory, we observed significant variation in the experimental group as a function of pre and post-tests for Digit Span forward and backward. In contrast to other executive functions measured, these results were not sustained at the one-month follow-up. Post-hoc testing was conducted to investigate inconsistencies.

The main effect of video game play had a significant effect on Digit Span forward scores for time, ($F(2, 44) = 3.82$, $p = .030$, $\eta^2_p = .15$), although neither the effect of group ($F(1, 22) = 2.04$, $p = .168$, $\eta^2_p = .09$), nor the interaction between time and group were significant ($F(2, 44) = 2.10$, $p = .135$, $\eta^2_p = .09$). Figure 3 shows the means for each group. Means examination revealed the experimental group improved from T1 to T3 at a low but steady rate. The control group means increased fractionally at each test point. Unadjusted pairwise comparisons indicated significant differences between T2 to T3 ($p = .044$) and T1 to

T3 (p = .037); however, comparisons were not significant when a Bonferroni adjustment was applied.

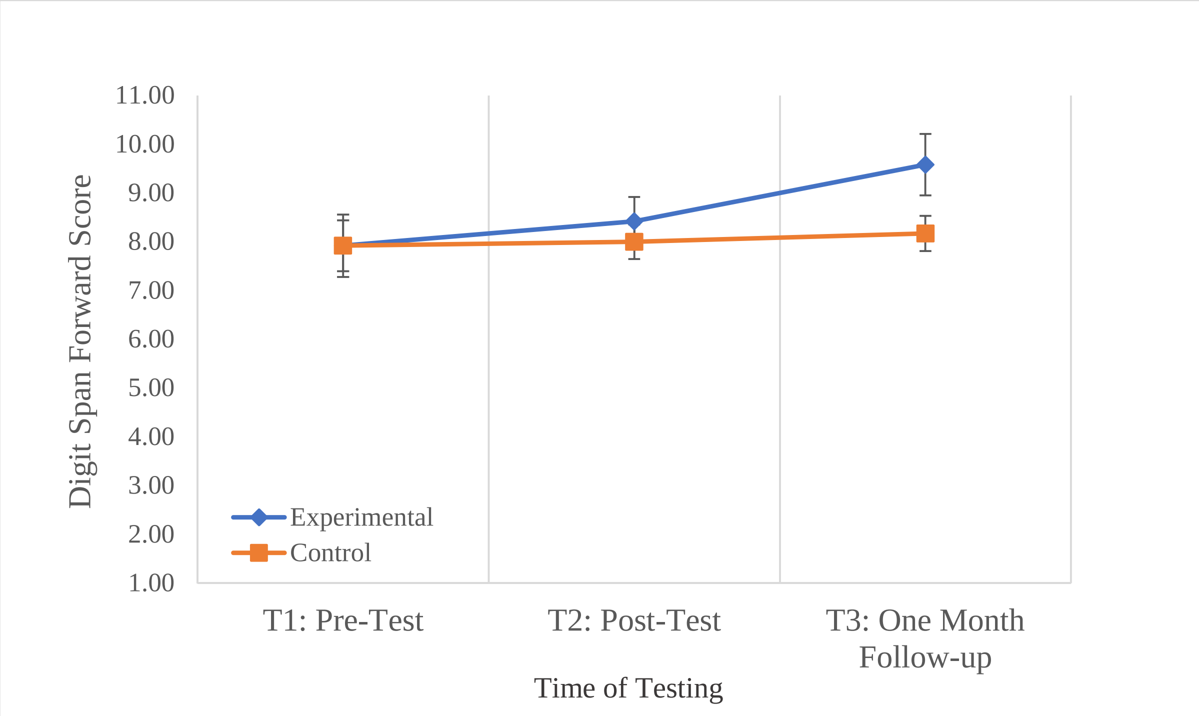

Figure 3. Digit Span forward mean numerical scores plotted as a function of time of testing. The error bars are the standard error of the mean.

Video game play did not exert a significant main effect on Digit Span backward, as a function of time (F(2, 44) = 0.56, p = .574, η^2_p = .03); however, the effect of group on performance was significant, (F(1, 22) = 5.52, p = .028, η^2_p = .20). The interaction between time and group was not significant (F(2, 44) = 1.38, p = .263, η^2_p = .06). Figure 4 shows the means and standard deviations. Bonferroni-adjusted t-tests were used to compare the experimental and control groups at T1, T2, and T3, revealing significance between groups at T2 (p = .014). Means examination revealed the experimental group improved from T1 to T2 but regressed at T3. The control group deteriorated from T1 to T2, then reverted to baseline at T3.

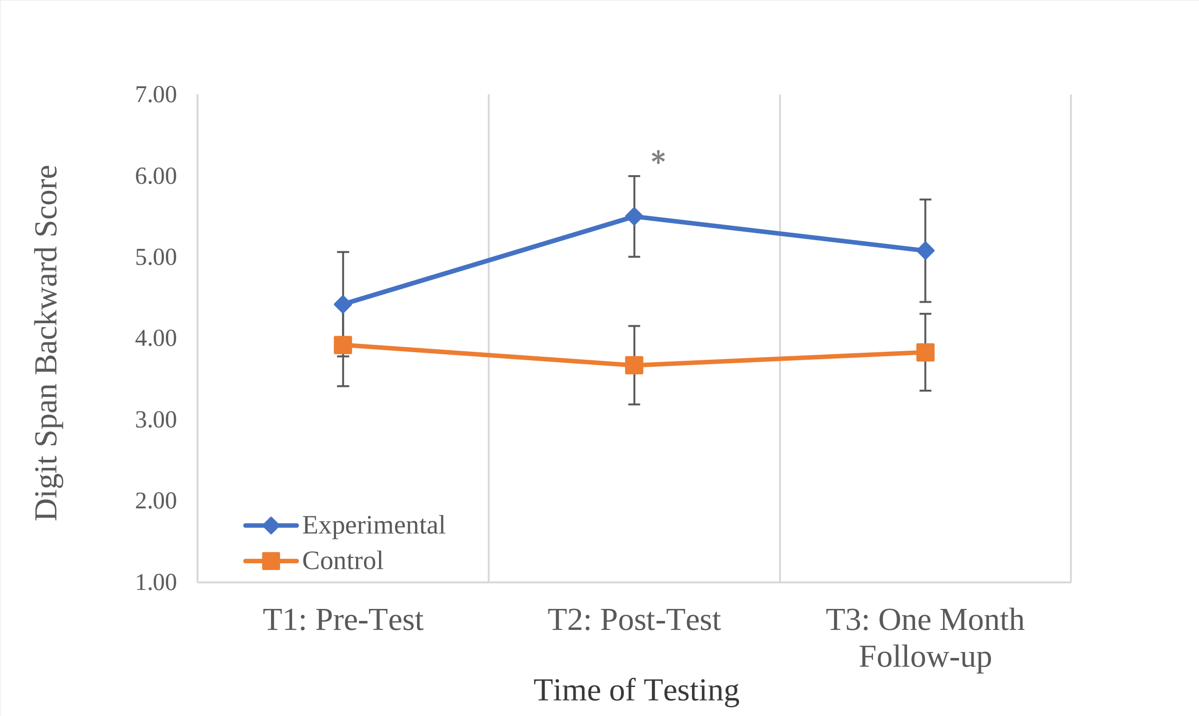

Figure 4. Digit Span backward mean numerical scores plotted as a function of time of testing. An asterisk at T2 marks the significant pairwise comparison at $p < .05$. The error bars are the standard error of the mean.

Figure 5 displays the Letter-Number Sequencing scores for each group. The main effects of time ($F(2, 44) = 1.48$, $p = .239$, $\eta^2_p = .06$), and group ($F(1, 22) = 2.49$, $p = .129$, $\eta^2_p = .10$) did not differ significantly across the two groups; however, these contrasts did yield medium effect sizes. The interaction between time and group approached but did not meet significance, with a medium effect size ($F(2, 44) = 3.13$, $p = .053$, $\eta^2_p = .13$). Pairwise comparisons within ANOVA were not significant; however, post-hoc Bonferroni adjusted t-tests revealed a significant difference at T2 between the experimental and control groups ($p = .004$). The experimental group improved at T2, but regressed toward baseline one month later, while the control group showed a slight deterioration at T2, followed by improvement at T3.

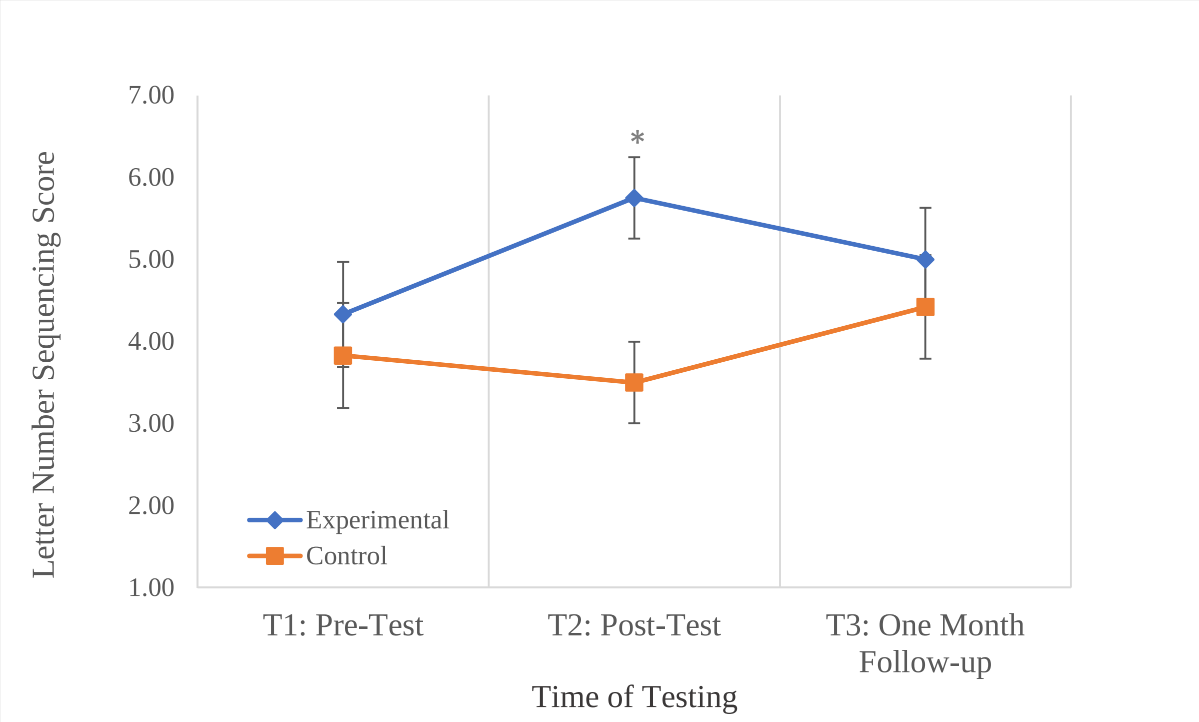

Figure 5. Letter Number Sequencing mean numerical scores plotted as a function of time of testing. An asterisk at T2 marks the significant pairwise comparison. The error bars are the standard error of the mean.

3.4. Quality of Life

Both the experimental and control groups showed minor increases in Older Person's Quality of Life scores at each successive time point. Figure 6 shows the change in the dependent variable as a function of pre and post-tests for both groups. The main effect of time was not significant ($F(2, 44) = 0.61$, $p = .550$, $\eta^2_p = .03$) nor was the main effect of group ($F(1, 22) = 0.30$, $p = .590$, $\eta^2_p = .01$). No significant interaction between time and group was found ($F(2, 44) = 0.12$, $p = .888$, $\eta^2_p = .01$). Pairwise comparisons were not significant; mean differences between groups across repeated measures were minimal.

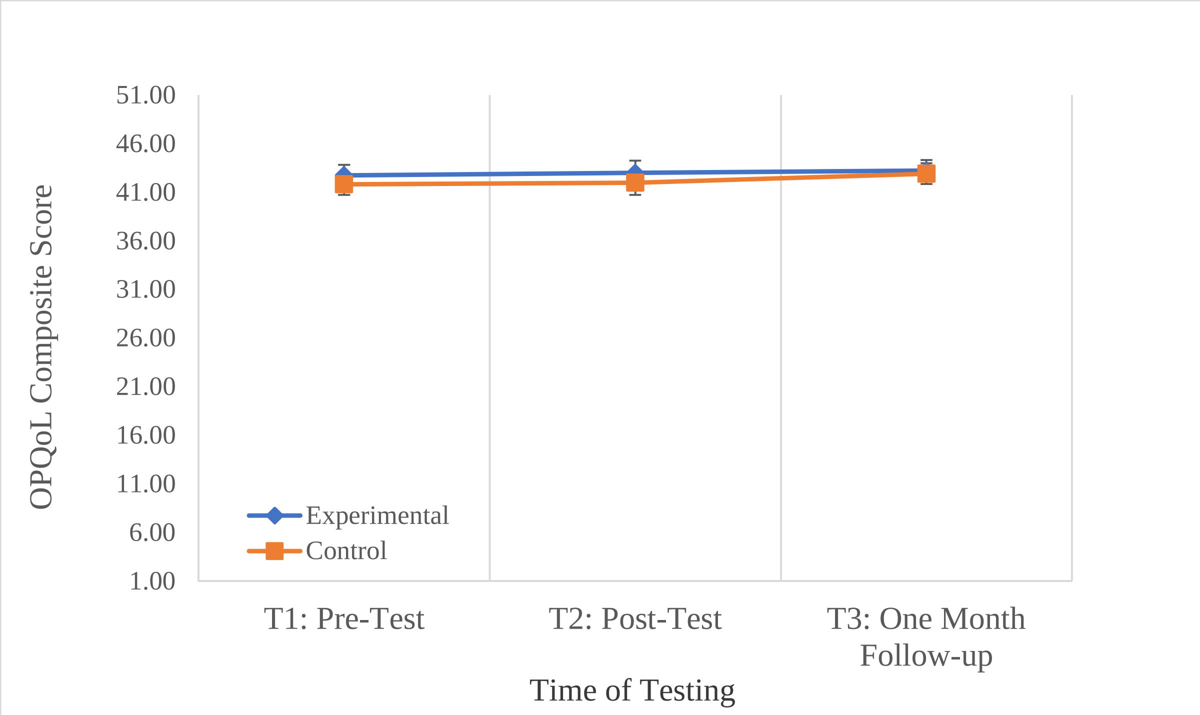

Figure 6. Older Person's Quality of Life mean numerical scores plotted as a function of time of testing. The error bars are the standard error of the mean.

4. Discussion

The experimental group showed improvement on visual attention and task switching with large effect sizes, commensurate with past studies below age 80 using CRI games (Anguera et al., 2013; Stern et al., 2011), and action games (Belchior, 2008; Belchior et al., 2013). The effects of play continued to grow one-month post-intervention, extending previous literature on the healthy oldest-old that did not include longitudinal follow-up. Further, the interaction of time and group on the different measures in the present paper were the critical effects of interest as it informs whether there were group differences over time; for both visual attention and task switching, this interaction was statistically significant. Given that impaired task-switching is often associated with Parkinson's disease (PD) (Monchi et al., 2004; Sawada et al., 2012), and that individuals living with PD are five times more likely to live in residential aged care facilities (Kerr, Mellick, Double, Creswell, & Ayton, 2014) the results of the current study may support action game playing as a means of mitigating the symptoms of PD. Alternatively, as suggested by Vichitvanichphong et al.

(2016), game playing may provide cost-effective, risk-aversive assessment options; as a consequence, action game playing may be able to help to identify individuals with PD, before other symptoms (e.g., tremors) appear.

The effects of video game play on working memory results were less straightforward than the other measures. The experimental group showed significant improvement on two measures of working memory with large main effect sizes, the Digit Span forward and backward. However, interactions between time and group were not significant, and gains for the backward measure regressed after one month. Experimental participants showed a similar trajectory on the third working memory measure, Letter-Number Sequencing, where post-test gains receded after one month. The inconsistent pattern of working memory results echoed those in previous literature; some showed null effect (Boot et al., 2013), while others showed large effects (Anguera et al., 2013; Strenziok et al., 2014). It appears that task switching and visual attention showed noticeable and lasting improvement after a short intervention, while the improvement in working memory in comparison was smaller and did not persist.

Three potential explanations for the working memory results were considered — the first explanation may lie within the requirements of the game itself. Informal observation of participant game play by the researcher suggested that task switching and visual attention were challenged more rigorously than working memory; it was unnecessary to recall details from previous waves to play successfully. This lesser challenge may have yielded less significant results. Another explanation might be a practice effect. Of the three working memory measures used, only Letter-Number Sequencing has been validated against practice effects within one month, specifically (Lo et al., 2012), and may provide a more accurate reflection of the accrued benefit. Practice effects may also help explain why the control group experienced some improvement, although not statistically significant, between T2 and T3 testing. A third explanation could be that in order to sustain working memory benefit, game play should be ongoing; that is, one needs to use it regularly if one does not want to lose it.

Quality of life, as measured, does not appear to be influenced by video game play. Both groups showed insignificant gains at each test point, with minor improvement across groups potentially resulting from increased individual attention due to participation. This is, however, considered likely due to the game itself having minimal perceived short-term improvements. While it was thought that the restricted, structured environment of an aged-care facility would better facilitate a perceived transfer effect, this can only occur when the individual is aware of improvement. Unlike working memory function where improvements are more likely to reach conscious awareness, visual attention, and task-switching improvements are less obvious. As a result, it is still possible that a game that involves greater working memory "exercise" may lead to more obvious short-term improvements which, through the perceived transfer effect, will then lead to improved functionality in real-world situations and subsequent improvements to QoL.

Older adults generally move into residential care due to an inability to live independently (Australian Productivity Commission, 2015). Given the small sampling frame and the special nature of the participants, as well as the in-situ nature of the present study, neither health conditions nor use of medications was controlled, which could be considered a limitation. However, we did attempt to reduce the impact of variables that were beyond our control when recruiting participants by randomly assigning participants to conditions. Additionally, none of the participants were known to have experienced any change in medications while participating in this study. Consequently, we think it unlikely that health and medication contributed systematically to differences between the groups. In our sample of participants, 13% more women participated than the national proportion of women to men in residential care (Australian Institute of Health and Welfare, 2018). Future research could target a larger sample with a greater proportion of men while controlling for medication and health conditions. We attempted to attenuate expectancy effects or demand characteristics in the design by wording the materials and controlling interactions with the participant to avoid leading suggestions about possible cognitive benefits of video game play; however, if participants expected their game play to improve cognition, this may have affected performance.

Limitations notwithstanding, the results extend existing research by testing the duration boundary with an intervention yielding significant results 66% shorter than the briefest training period able to be identified (Belchior et al., 2008; 2013). Additionally, elements including a longitudinal follow-up, the use of action games in residential aged care, and isolation of participants over age 80 had not been previously combined. The correlation of increasing benefit with age suggested by Toril et al. (2014) cannot be supported by these results alone; however, given that significant improvement was also found in an older age group strongly supports further research into gaming and the oldest-old.

5. Conclusions

While gaming is often considered a youth pastime if not child's play, it is this play aspect that may make recreational (as opposed to educational) gaming a useful and valid intervention for maintaining cognitive health into old age. As demonstrated in the current study, action gaming shows clear, sustained improvement in some cognitive abilities. More importantly, the low participant attrition rate suggests that the participants found the intervention interesting or enjoyable; as noted by Anguera and Gazzaley (2015), one of the biggest challenges to any cognitive training regime is adherence. The results reported here cannot definitively prove that action gaming is good for the aging human brain; they do, however, strongly suggest that recreational gaming, where the primary goal is to have fun, can be beneficial. As a consequence, it seems reasonable to suggest that aged care facilities add recreational gaming to their programmed or optional leisure activities.

6. References

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