The Cognitive Effects of Nonaction Video Games: A Study on Attention and Memory in Young Adults

Prof. Ashok Pandey,

Distinguished Scientist, Indian Institute of Toxicology Research, Lucknow

Abstract

Objective: In this intervention study, we investigated the benefits of nonaction videogames on measures of selective attention and visuospatial working memory (WM) in young adults.
Materials and Methods: Forty-eight young adults were randomly assigned to the experimental group or to the active control group. The experimental group played 10 nonaction adaptive videogames selected from *Lumosity*, whereas the active control group played two nonadaptive simulation-strategy games (*SimCity* and *The Sims*). Participants in both groups completed 15 training sessions of 30 minutes each. The training was conducted in small groups. All the participants were tested individually before and after training to assess possible transfer effects to selective attention, using a Cross-modal Oddball task, inhibition with the Stroop task, and visuospatial WM enhancements with the Corsi blocks task.
Results: Participants improved videogame performance across the training sessions. The results of the transfer tasks show that the two groups benefited similarly from game training. They were less distracted and improved visuospatial WM.
Conclusion: Overall, there was no significant interaction between group (group trained with adaptive nonaction videogames and the active control group that played simulation games) and session (pre- and post-assessment). As we did not have a passive nonintervention control group, we cannot conclude that adaptive nonaction videogames had a positive effect, because some external factors might account for the pre- and post-test improvements observed in both groups.

Keywords: Cognitive training, Selective attention, Executive functions, Videogames, Visuospatial working memory, Young adults

Introduction

OVER THE past few decades, the number of publications focused on neurocognitive training with videogames has increased substantially.[1] These studies cover from educational[2] to clinical rehabilitation,[3] and include participants from different age stages.[4–10] Videogames are virtual environments that motivate, engage, and generate positive emotions that help people to keep training.[11–15]

Despite the great interest that it has generated, there is no consensus on the cognitive benefits of brain-training games.[16–23] The results of several meta-analyses suggest that brain training with videogames and other computerized programs improves aspects of cognition, in young and in older adults,[24,25] whereas a meta-analysis reported small or null overall effect sizes.[26] As a consequence of these mixed results, some authors have proposed that the appropriate design for these interventions is a double-blind, placebo controlled, and randomized study with an adequate active control.[27–31]

In this intervention study, participants were randomly assigned to an experimental group or an active control group, with the same number of training sessions and identical conditions. Participants in the experimental group played adaptive nonaction videogames from *Lumosity*, whereas those in the active control group played simulation games, previously used as active control condition[32–34] We also controlled for placebo effects by assessing motivation,

[1]Studies on Aging and Neurodegenerative Diseases Research Group, Department of Basic Psychology II, Facultad de Psicología, Universidad Nacional de Educación a Distancia (UNED), Madrid, Spain.
[2]Department Methodology of the Behavioral Sciences, Facultad de Psicología, Universidad Nacional de Educación a Distancia (UNED), Madrid, Spain.

engagement, and expectations. We hypothesized that young adults in the experimental group would transfer the abilities developed as a result of the videogame training to visuospatial working memory (WM) and to aspects of attention including distraction, alertness, and controlled inhibition of interference.

Materials and Methods

Participants

Forty-eight volunteers between 18 and 35 years of age were recruited from flyers and project presentations at university lectures; they received 85e for travel costs. We included participants from 18 to 35 years of age because this age range is normally identified with early adulthood[49] and has previously been used in other young adult intervention studies.[50] All participants had normal hearing and vision and were free of neurological or psychiatric disorders. Exclusion criteria were depression (>15 points on Beck Depression Inventory, BDI), <20/60 vision with or without correction, inability to complete training, and communication problems. They completed a screening test battery consisting of the information subtest of the WAIS-III scale,[35] the short version of the BDI[36] and the quality of life questionnaire from the World Health Organization (WHOQOL-BREF).[37] The WAIS-III was validated using common factor analysis, showing that the four factors accounted for 61% of the total variance.[51] The WHOQOL-BREF had good internal consistency[52] in terms of Cronbach's a (physical domain = 0.73, psychological domain = 0.80, social domain = 0.62, and environment domain = 0.71). The BDI has shown acceptable reliability (Cronbach's $a = 0.83$).[53]

For assessment of the placebo effect, we used questionnaires based on two studies that did not report validity coefficients.[30,42] However, other researchers have adapted the questionnaires[30] producing the expectation assessment scale and analyzed their psychometric properties.[54] They reported an internal consistency of 0.87.

The cognitive assessment tasks are not usually analyzed psychometrically in terms of their validity and other psychometrical properties, but the Stroop test showed a convergent validity of -0.35 y -0.41 for the three subscales (Word, Color, Word-Color). Moreover, its construct validity was assessed by a factorial analysis and the three components explained 47%, 23%, and 16% of the total variance, respectively.[55]

Participants were randomly assigned to the experimental or to the active control group using the random generator of integer numbers from Matlab. There were no differences between groups at pretest in outcome variables (Table 1). The gender ratio and educational level of our sample differed slightly from the Spanish population of the same age; females represented 66.7% of our sample and males 33.3%, compared with 50.78% and 49.22%, respectively, in the general population. For educational level, 79.8% of our participants had completed secondary education compared with only 10.3% of the Spanish population; 15.5% of our participants had completed higher education compared with 6.4% of the Spanish population.

Participants gave their informed consent. The study was conducted in accordance with the Declaration of Helsinki.[38] No participants were excluded after screening. Nine of the 48 participants (18.75%) were lost at post-test. The study was thus completed by 18 out of 24 participants in the experimental group and by 21 out of 24 participants in the control group.

We conducted an a priori power analysis (G-Power 3.1.9.2) to calculate the value of a sufficient sample size.

Table 1. Demographic Information

Characteristics	*Experimental group,* n = *18*	*Active control group,* n = *21*	F	P	l^2_q
Age, years	22.78 (4.83) [18–33]	22.48 (4.07) [18–32]	0.04	0.83	0.001
Gender, *N* (%)					
Female	12 (66.7)	14 (66.7)			
Male	6 (33.3)	7 (33.3)			
Education, *N* (%)					
High school/some college	14 (77.8)	17 (81)			
College degree	3 (16.7)	3 (14.3)			
Postgraduate degree	1 (5.6)	1 (4.8)			
BDI pretest	3.17 (2.33) [0–9]	3.95 (4.22) [0–15]	0.51	0.482	0.013
BDI post-test	1.89 (2.32) [0–8]	3.14 (3.58) [0–14]	1.62	0.21	0.042
Information (WAIS)	19.28 (3.86) [14–26]	20.19 (4.10) [10–25]	0.51	0.482	0.013
WHOQOL pretest					
D1 (physical health)	27.5 (3.74) [22–34]	27.28 (3.99) [21–35]	0.03	0.86	0.001
D2 (psychological health)	22.24 (1.98) [19–27]	22.14 (3.44) [15–27]	0.11	0.74	0.003
D3 (social relationships)	11.61 (2.09) [7–14]	12.28 (1.95) [8–15}	1.08	0.3	0.028
D4 (environment)	30.05 (3.98) [24–37]	29.71 (4.78) [17–37]	0.058	0.81	0.002
WHOQOL post-test					
D1 (physical health)	26.89 (3.94) [17–33]	28.05 (3.93) [20–34]	0.84	0.36	0.02
D2 (psychological health)	23 (2.7) [16–28]	21.95 (3.84) [13–27]	0.94	0.34	0.025
D3 (social relationships)	11 (1.97) [7–14]	11.71 (2.19) [7–15]	1.13	0.29	0.03
D4 (environment)	31.83 (4.42) [24–40]	29.81 (4.98) [19–37]	1.77	1.19	0.04

Mean, standard deviation (in parentheses), range [in brackets], *F* values of ANOVAs, *P* or significance level, and effect size l^2_p.
BDI, Beck Depression Inventory.

Using an α of 0.05, a power of 0.80, and a medium effect size ($d = 0.29$),[39] a sample of 38 participants would be sufficient to detect significant interaction effects. Accordingly, the adequate number of participants in each group is * 19 participants. Scores of dropout participants after pre-test did not differ from those who continued in the study: Corsi task ($t_{45} = -0.25$, $P = 0.81$), Stroop ($t_{45} = 1.37$, $P = 0.21$), and Oddball task (silence condition: $t_{45} = -4.42$, $P = 0.68$, standard condition: $t_{45} = -0.9$, $P = 0.92$, novel condition: $t_{45} = 0.52$, $P = 0.96$; distraction effect: $t_{45} = 0.53$, $P = 0.59$: alertness effect: $t_{45} = 0.68$, $P = 0.50$).

Our power calculations did not take into account loss of data, so we performed a test to evaluate the missingness pattern of our actual data. The results of this analysis showed that the data were missing completely at random (MCAR) in the Corsi blocks test, the Oddball task, and the Stroop test (Little MCART test: chi-square = 2.781, Degree of Freedom (DF) = 6, $P = 0.836$; Little MCART test: chi-square = 0.926, DF = 5, $P = 0.968$; Little MCART test: chi-square = 0.000, DF = 3, $P = 1.000$, respectively).

We also performed an intention-to-treat (ITT) analysis by the multiple imputation of missing values through the maximum likelihood estimation procedure with five replications. The result of this ITT analysis is reported adding a mean P-value ($\overline{P}$) on significant effects of the main nonimputed analysis.

Cognitive evaluation: tasks and procedures

Attentional tasks. We assessed distraction and alertness with the Cross-modal Oddball task, and effortful inhibitory control with the Stroop task.

Cross-modal Oddball attention task. The task comprised three blocks of 384 trials each (24 practice trials and 360 test trials). In each trial, participants categorized a visual digit from 1 to 7 as odd or even by pressing one of two response keys, which were counterbalanced across participants. Each trial began with the presentation of a white fixation cross in the center of a gray screen together with a 200 ms sound. The digit appeared in white in the center of the screen 100 ms after the sound's offset and remained on the screen for 200 ms. A response window was displayed for 1200 ms from the digit's onset. There were three conditions: silent in one block of trials and two different sounds (standard and novel) in two blocks. The standard sound (80% of the trials) consisted of a 600 Hz sine-wave tone of 200 ms, and the novel sound, used in 20% of the trials, was taken from a list of 72 environmental sounds (hammer, drill, door, rain, etc.). See Ballesteros et al.[40] for a detailed description.

Stroop task. The Stroop task assesses controlled effortful inhibition. The stimuli were three color words (''red'', ''green'', or ''blue'') presented in three colors (red, green, or blue) in the center of the screen. Participants responded by pressing the appropriate key of the computer, which were counterbalanced across participants. Each trial started with a black fixation cross, which appeared in the center of the screen on a white background. Stimuli were presented randomly for 200 ms. Participants responded as quickly and accurately as possible by pressing the key corresponding to the color of the stimulus word while ignoring its semantic meaning. See Ballesteros et al.[40] for a detailed description.

Visuospatial WM. *Corsi blocks task.* We used a computerized version of the Corsi blocks task with six levels of increasing difficulty (2, 3, 4, 5, 6, and 7 cube positions) and 12 trials per level. The stimuli consisted of black squares that appeared one by one in the center of the computer screen inside a $3 \cdot 3$ matrix for 1000 ms each, with a 500 ms interstimulus interval. The final score was the proportion of correct sequences reproduced at each difficulty level.

Assessment of motivation, engagement, and expectation. Motivation was assessed at pre- and post-test using a 10-point Likert-type scale (1 = not motivated, to 10 = extremely motivated). Participants were asked how engaged they felt during the pretest and post-test (1 = not engaged at all, 10 = extremely engaged on the task).

Expectations were assessed at pretest and post-test by asking participants to indicate on a 5-point Likert-type scale how much they thought their overall performance on the experimental tasks would improve after videogame training (1 = the results will be much worse, 3 = there will not be any change, 5 = the results will be much better). We also evaluated differences in expectations of improvement after training on each specific experimental task. Participants were asked to indicate what they thought the effects of training would be on each assessment task (1 = the results will be much worse, 3 = there will not be any change, 5 = the results will be much better). Finally, participants reported (1 = no improvement to 5 = great improvement) how much they thought they had improved in various skills (daily life activities, attention, visual acuity, memory, speed of processing, current studies, and emotions) as a consequence of their participation in the project.

The training program

Participants in the experimental group played 10 videogames from *Lumosity* in a randomized order while the active control group played 2 simulation games (*SimCity*, *The Sims*; Electronic Arts, Inc.) (Table 2). The selected *Lumosity* games were those that train the following cognitive domain: executive functions, speed of processing, attention, and memory, all of them fundamentals for global cognition. The *SimCity* and *Sims* games were not specifically designed to train cognitive skills and the difficulty level was not adaptive. Previous young adult studies used *The Sims* as the active control condition.[41,42] Both groups completed 15 training sessions (30–35 minutes per session) in subgroups of 8–15 participants in the presence of the trainer over a period of 3–4 weeks. Each participant was given a tablet (Brigmton BTPC 1018OC) and a headphone. Approximately, each participant played for a total of 7.5 hours.

Results

In all the analyses, we used an α of 0.05. All the statistical tests were Bonferroni corrected for multiple comparisons.

Videogame performance across training sessions

To assess performance in the experimental group, we analyzed the mean accuracy performance on Z-scores for each of the 10 games that participants played during the

Table 2. Description of the Videogames

Game name Lumosity	*Training function*	*Description*
Experimental group		
Tidal treasures	Working memory	You have to choose objects and memorize your choice.
Pinball recall	Working memory	You have to predict a balls' path.
Playing Koi	Divided attention	You have to feed some fish, remembering those that you have already fed.
Star search	Selective attention	There is a bunch of objects and you have to choose the one that is different.
Lost in migration	Selective attention	A flock of birds will appear on the screen and you have to swipe in the direction the middle bird is facing.
Color match	Response inhibition	You have to compare one word's meaning to another word's color.
Disillusion	Task switching	You have to solve a puzzle, matching titles with different shapes, colors, or symbols.
Ebb and flow	Task switching	Leaves appear on the screen; you must swipe in the direction they are moving or pointing toward.
Highway hazards	Information processing	You have to race a car across the desert avoiding colliding with the obstacles that you will encounter.
Speed match	Information processing	A card appears on the screen and you must determine whether it is the same as the previous one.
Control group		
SimCity BuildIt	None	Life simulation game in which the player is the mayor of a city that he or she must expand.
The Sims (free to play)	None	Life simulation game in which the player creates characters (*Sims*) who live in a virtual world that is similar to the real world. *Sims* have to work, build their homes, plan activities, etc.

training period. Videogames performance significantly improved across sessions ($P < 0{:}01$ in all cases) (Fig. 1).

To measure the game performance of the control group, we analyzed two main measures provided by both simulation games: average experience level (mean = 14.84; standard deviation = 4.32) and city population (mean = 32942; standard deviation = 22597). *T*-test revealed a significant difference between the first and the last training sessions for both measures (experience level: t_{36} = -11.09; $P < 0.01$ and city population: t_{36} = -6.19; $P < 0.05$).

Motivation, engagement, and expectations

Mixed measures ANOVAs with 2 groups (experimental, active control group) · 2 sessions (pre, post) were conducted separately for motivation, engagement, and expectations.

Motivation. The ANOVA showed a significant effect of group [$F(1, 36) = 6.4$; mean square error (MSE) = 1.34; $P = 0.001$; $g^2 = 0.15$; $1 - b = 0.69$]. The experimental group was more motivated (8.03) than the active control group (7.07). Session was also significant [$F(1, 36) = 12.15$; MSE = 0.94; $P = 0.001$; $g^2 = 0.25$; $1 - b = 0.92$]. Motivation was lower at post-test (7.16) than at pretest (7.94). There was not significant interaction between group and session.

Engagement. The ANOVA showed that group was significant [$F(1, 37) = 6.80$; MSE = 1.49; $P = 0.001$; $g^2 = 0.15$; $1 - b = 0.72$]. The experimental group was more engaged (7.33) than the active control group (6.31). The effect of session was also significant [$F(1, 37) = 12.46$; MSE = 0.92; $P = 0.001$; $g^2 = 0.25$; $1 - b = 0.93$]. Participants were more engaged at pretest (7.21) than at post-test (6.44). There was not significant interaction between group and session.

Expectations. To assess the reliability of this scale, we combined the items in a global index and computed Cronbach's *a*. Our results show a reliability of 0.64 for expectations and 0.86 for perceived improvement.

An ANOVA with group and session showed that there was a significant effect of group [$F(1, 37) = 7.80$; MSE = 0.18; $P = 0.008$; g¾0.99; $1 - b = 0.78$]. The experimental group holds higher expectations (4.03) than the control group (3.64) and a significant effect of session [$F(1, 37) = 11.09$, MSE = 0.33; $P = 0.002$; $g^2 = 0.23$; $1 - b = 0.9$]. Expectations were higher at pretest (4.05) than at post-test (3.62). There was no interaction between group and session.

Moreover, expectations of improvement after training on the experimental tasks were assessed using a 3 tasks · 2 groups mixed ANOVA. The analysis showed that there was a significant effect of experimental task expectations [$F(2, 74) = 4.69$; MSE = 0.46; $P = 0.012$; g^2 ¼ 0.11; $1 - b = 0.77$]. Expectations were higher for the Corsi (3.86) than the Oddball (3.43). Group was also significant [$F(1, 37) = 9.03$; MSE = 0.65; $P = 0.005$; g^2 ¼ 0.196; $1 - b = 0.83$]. The experimental group had higher expectations (3.81) than the control group (3.36).

We also assessed differences in expectations regarding daily life activities, memory, processing speed, attention, visual acuity, and emotions as a consequence of their participation in the project, using a 5-point Likert-type scale. *T*-tests showed that there were no main differences between groups for daily life activities ($t_{37} = 0.77$; $P = 0.44$), attention ($t_{37} = 0.78$; $P = 0.44$), visual acuity ($t_{37} = 1.44$; $P = 0.16$), current studies ($t_{37} = 0.31$; $P = 0.76$), and emotions ($t_{37} = 1.02$; $P = 0.31$). However, there were significant differences between groups in their expectations regarding improvements in memory ($t_{37} = 3.14$; $P = 0.003$). Expectations regarding memory transfer were higher in the experimental group (3.06) than in the control group (1.71).

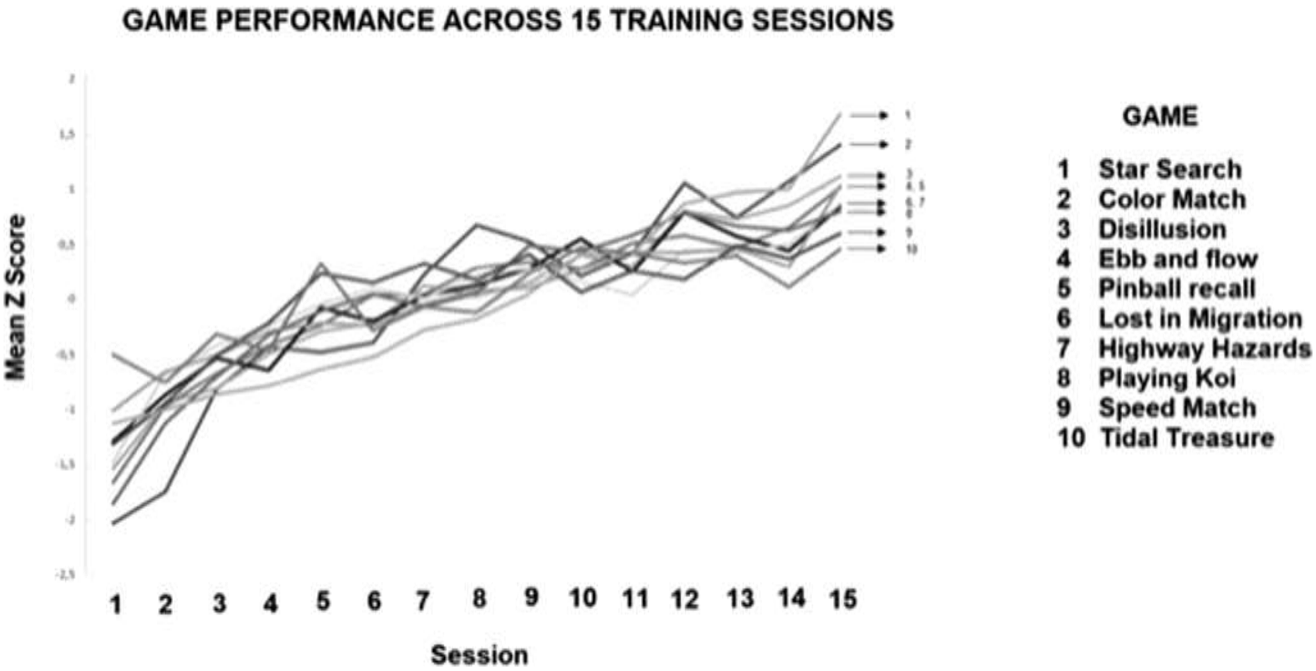

FIG. 1. Average performance scores obtained in each videogame across the training sessions in *Z* scores (mean 0; standard deviation 1).

Transfer effects of videogame training to the experimental tasks

The main results obtained in the transfer tasks by both groups are given in Table 3.

Attentional effects. *Cross-modal Oddball task.* We conducted a 2 group (experimental, active control group) · 2 session (pretest, post-test) · 3 sound conditions (silence, standard sound, and novel sound) mixed ANOVA on the reaction times (RTs) of the correct responses after deleting outliers (RTs <200 ms and >1500 ms). The multivariate analysis showed the following results: Wilks's ﬂ (session) = 0.09, $F(1, 271) = 23.6$; $P = 0.001$; Wilks'ﬂ (session · group) = 0.93, $F(2, 271) = 9.92$; $P = 0.001$; Wilks'ﬂ (sound condition) = 0.35, $F(2, 270) = 251.75$; $P = 0.001$. As these statistics were significant, we examined the univariate results. The results showed a main effect of session [$F(1, 37) = 4.70$; MSE = 2614.3; $P = 0.04$; $\overline{P} = 0.05$; g^2 ¼ 0:11; 1 – $b = 0.56$]; RTs were significantly faster at post-test (552 ms) than at pretest (567 ms). The session by group interaction was significant [$F(1, 37) = 3.98$; MSE = 2614.3; $P = 0.05$; $\overline{P} = 0.23$; $g^2 = 0.09$; 1 - $b = 0.94$]; post hoc pairwise comparisons showed that only the experimental group significantly improved from pretest (577 ms) to post-test (549.1) ($P < 0.05$). The main effect of sound was also significant [$F(1.7, 61.9) = 32.68$; MSE = 612.6; $P < 0.001$; $P = 0.001$; $g^2 = 0.47$; 1 – $b = 1$]; RTs were faster under the standard sound condition (544 ms) than under the silence (573 ms) and novel sound (561 ms) conditions ($P < 0.01$), but not between silence and novel sound conditions. No other interaction was significant.

We conducted additional analyses on *distraction* and *alertness*. The distraction effect was calculated as the difference between the RTs in novel sound trials and the RTs in the standard sound trials. A 2 group · 2 session mixed ANOVA performed on distraction showed that session was significant [$F(1, 37) = 26.56$; MSE = 148.7; $P < 0.05$; $\overline{P} < 0.01$; $g^2 = 0.42$; 1 - $b = 0.99$]. Distraction at post-test significantly decreased compared with pretest for both the experimental group (pretest = 27 ms; post-test = 16 ms) and the control group (pretest = 21 ms; post-test = 4 ms). No other effect or interaction was significant.

Alertness was calculated as the difference between RTs under the silence condition and RTs under the standard sound condition. The 2 group · 2 session mixed ANOVA showed neither a significant main effect nor an interaction (all P's > 0.05).

Stroop task. Responses were coded according to the congruency between the color and the meaning of the word. Outliers (1% of the trials) were defined as RT responses <200 ms and >1500 ms.

We conducted a 2 group · 2 session · 2 congruency condition (congruent, incongruent) mixed ANOVA on the mean RTs for correct trials as the dependent variable. The multivariate analysis showed the following results: Wilks'ﬂ (congruency) = 0.21, $F(1, 37) = 140.85$; $P = 0.001$. As these statistics were significant, we examined the univariate results. Congruency was significant [$F(1, 37) = 140.85$; MSE = 662.83; $P < 0.01$; $P = 0.005$; $g^2 = 0.79$; 1 - $b = 1$]. Congruent trials were faster than incongruent trials. There were no further significant main effects or interactions (all P's > 0.05). We also computed the Stroop effect as the difference between incongruent RTs and congruent RTs. A 2 group · 2 session mixed ANOVA showed that neither the main effects nor the interaction effects were significant (all P's > 0.05).

Effects of training on Corsi blocks. We performed a mixed 2 group · 2 session · 6 Corsi level (2, 3, 4, 5, 6, and 7) ANOVA with the last two factors within subjects. The

TABLE 3. PRE- AND POST-TRAINING PERFORMANCE ON PSYCHOLOGICAL MEASURES FOR THE EXPERIMENTAL AND CONTROL GROUPS

Measures	*Pre-Exp G.*	*Post-Exp G.*	*Pre-CTL G.*	*Post-CTL G.*	*Hedges'* g *with CI*
Corsi blocks task					
2. Serial position[a]	0.99 (0.04)	0.98 (0.06)	1 (0)	0.99 (0.02)	0 [-0.63 to 0.63]
3. Serial position	0.87 (0.05)	0.82 (0.14)	0.87 (0.08)	0.88 (0.07)	0.8 [0.2–1.5]
4. Serial position[a]	0.8 (0.22)	0.87 (0.21)	0.85 (0.12)	0.92 (0.08)	0 [-0.63 to 0.63]
5. Serial position[a]	0.56 (0.28)	0.73 (0.19)	0.69 (0.19)	0.75 (0.16)	-0.46 [-1.1 to 0.18]
6. Serial position[a]	0.42 (0.28)	0.48 (0.26)	0.54 (0.23)	0.63 (0.25)	0.11 [0.52–0.75]
7. Serial position[a,b]	0.15 (0.16)	0.27 (0.22)	0.28 (0.21)	0.39 (0.26)	-0.05 [-0.69 to 0.58]
Stroop task					
Stroop congruent condition, ms	653.5 (90.16)	652.1 (97.48)	636 (110.71)	646.89 (99.4)	0.12 [0.52–0.75]
Stroop incongruente condition, ms	704.4 (94.62)	701.9 (105.69)	686.2 (119.9)	692.27 (103.27)	0.08 [-0.56 to 0.71]
Stroop effect, ms[a]	50.92 (19.16)	49.8 (38.38)	50.17 (31.10)	45.39 (26.37)	-0.14 [-0.77 to 0.5]
Oddball task					
Oddball silence condition	588.1 (81.8)	563.35 (99.54)	568.82 (72.26)	573.37 (71.72)	0.37 [-0.27 to 1.01]
Oddball standard condition	557.93 (75.80)	534.09 (86.06)	539.95 (66.99)	544.54 (57.97)	0.4 [-0.25 to 1.03]
Oddball novel condition[a]	585.18 (82.70)	549.99 (91.14)	560.72 (71.92)	548.11 (66.87)	0.29 [-0.35 to 0.92]
Distraction, ms[a,b]	27.25 (24.62)	15.89 (18.13)	20.77 (14.99)	3.57 (20.03)	-0.29 [0.92–0.35]
Alertness, ms[a]	30.17 (37.08)	29.26 (30.15)	28.87 (32.88)	28.83 (28.12)	0.02 [-0.61 to 0.66]
Placebo effect					
Motivation	8.28 (1.23)	7.78 (1.06)	7.60 (1.57)	6.55 (1.43)	-0.38 [0.26 to -1.02]
Engagement	7.56 (0.98)	7.11 (1.68)	6.86 (1.24)	5.76 (1.58)	-0.56 [0.08 to -1.21]
General expectations	4.06 (0.54)	4 (0.68)	4.05 (0.38)	3.24 (0.7)	-1.59 [-0.86 to -2.33]
Task expectations Corsi		3.72 (0.57)		3.15 (0.79)	0.80 [0.15–1.45]
Task expectations Stroop		3.67 (0.68)		3.28 (0.78)	0.65 [0.01–1.30]
Task expectations Oddball		4.05 (0.72)		3.67 (0.73)	0.51 [-0.13 to 1.15]
Perceived improvement dailylife		1.67 (1.28)		1.38 (1.02)	0.25 [-0.38 to 0.88]
Perceived improvement attention		3.11 (1.37)		2.81 (1.03)	0.24 [-0.39 to 0.88]
Perceived improvement visual acuity		2.89 (1.57)		2.24 (1.26)	0.45 [-0.19 to 1.09]
Perceived improvement studies		1.83 (1.09)		1.71 (1.27)	0.10 [-0.53 to 0.73]
Perceived improvement emotions		1.72 (1.45)		1.28 (1.23)	0.32 [-0.31 to 0.96]
Perceived improvement memory[b]		3.05 (1.05)		1.71 (1.52)	0.99 [0.32–1.66]
Perceived improvement speed[b]		3 (1.14)		2.14 (1.49)	0.63 [-0.02 to 1.27]

Mean scores of the outcome measures with standard deviations in parentheses.
Effect size (Hedges' *g*) is the standardized mean difference for pre-/post-test designs with two groups (experimental and control). CI is the confidence interval of Hedges' *g*.
[a]Indicates that both groups improved after training.
[b]Indicates tasks on which there was a trend for large improvements in the experimental group.

multivariate analysis showed the following results: Wilks' fl (session) = 0.73, $F(1, 37) = 13.34$; $P = 0.01$; Wilks' fl (level) = 0.045, $F(5, 33) = 139.08$; $P = 0.001$; and Wilks' fl (session · level) = 0.66, $F(5, 33) = 3.45$; $P = 0.013$. As these statistics were significant, we examine the univariate results, which showed a significant main effect of level [$F(5, 185) = 203.89$; MSE = 0.03; $P = 0.001$; $\overline{P} = 0.001$; $g^2 = 0.85$; $1 - b = 1$] with lower scores as increasing level. Session was also significant [$F(1, 37) = 13.34$; MSE = 0.029; $P < 0.01$; $\overline{P} = 0.047$; $g^2 = 0.25$; $1 - b = 0.94$]. Participants performed better at post-test (0.73) than at pretest (0.67). The interaction between level and session [$F(3.5, 130) = 4.73$; MSE = 0.02; $P = 0.001$; $P = 0.001$; $g^2 = 0.113$; $1 - b = 0.97$] was also significant. Post hoc pairwise comparisons showed that both groups improved after training at levels 3 (0.82 and 0.89), 4 (0.62 and 0.74), and 6 (0.22 and 0.33), and marginally significant ($P = 0.059$) at level 5 (0.48 and 0.56 at pre- and post-test, respectively). No other effects or interactions were significant.

Discussion

This study yielded the following main results. First, participants' videogame performance improved across the training sessions.[8,10,40] Second, both groups were less distracted after training. Third, effortful inhibition did not show any improvement at post-test in either group. Fourth, visuospatial WM improved after training in both groups.

Our results did not show the expected effect of training. The interaction between group (the experimental group trained with nonaction videogames and the active control group trained with the nonadaptive simulation-strategy games) and session was not significant, except in the overall scores of the oddball task. The results revealed a similar effect of training in both groups, showing no differential effect of the type of videogames used (*Lumosity* and *SimCity*/*The Sims*). Since this study did not include a passive control group, we cannot conclude that the adaptive nonaction games had an effect, as some external factor might account for increases in both groups.

A recent study conducted with older adults trained with videogames from *Lumosity* and a control group that did not receive training showed that the trained group improved significantly on the Corsi blocks after videogame training, but a passive control group showed no change.[10] Most spatial cognition tasks depend on attention and WM capacities, which are closely interconnected,[45–47] but few studies have focused on visuospatial WM changes resulting from videogame practice in young adults. Nonetheless, this study also showed that the experimental group performed better than the control group at post-test on the Cross-modal Oddball task, but only for the global scores. This interaction did not show up in the distraction scores, suggesting that if there is any effect, it is very small. Some authors have suggested that players benefit in the control and allocation of selective attention. The shifting of mental set is a different executive function than updating of WM, inhibition of responses, and separable components of selective attention,[48] but most of the classic switching tasks assess all of these elements as a whole. However, Karle et al.[20] indicated that gamers have reduced task-switching costs due to their ability to control selective attention, rather than a more general benefit in cognitive control abilities. Thus, there are mixed results about selective attention, distraction, and attention capture. Further research is needed to clarify them. Stroop interference did not show any improvement after training in response inhibition in either group. These results are in agreement with findings from older adults.[40]

We hypothesized that playing adaptive brain games would improve visuospatial WM and attention. We tried to overcome some methodological limitations in other studies by including an active control group. The present results showed that nonaction videogames could mildly benefit young adults from pre- to postintervention, but the benefits were not exclusive to brain training games as we also found some cognitive improvement in the active control group. We assessed motivation, engagement, and expectations and they do not seem to explain the benefits derived from the videogame training. Based on these results, it seems that general expectations could not affect primary outcome measures because expectations were higher at pretest, but significant effects were found at the Oddball task and Corsi block test after training. Participants showed higher expectations at Corsi test than at the Oddball task, but both results were significantly higher at post-test.

Conclusions and Limitations

To conclude, we did not find a significant difference between adaptive nonaction videogames and the active control games used. As we did not have a nonintervention control group, we cannot conclude that adaptive nonactive videogames had an effect, because some external factor might account for observed increases in both groups. Thus, future studies should include both an active control group and a no-contact group. Moreover, our power calculations did not anticipate the loss of data due to outliers. Consequently, we performed a test for missingness of data at random, and the results showed that the data were missing completely at random in all the experimental tasks. A limitation of this study is that males were under-represented in our sample and highly educated young people were over-represented. This limitation could have produced some bias in our results and this should be addressed in future studies. Further research should include not only an active control group but also a passive control group to explore possible test–retest effects.

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Ethics Statement

The UNED's Ethical Review Board approved the study. All the participants gave their informed consent before the study started. They were informed of their right to terminate participation at any time. The work described in this article has not been published previously.

Data Statement

Data are available upon request.

Authors' Contributions

Conceptualization and study design were conducted by S.B. and J.M.; programming experimental tasks were carried out by J.M. and A.P.; E.R.-M. enrolled the participants, conducted the training sessions, and collected the data; data analyses were done by E.R.-M. with support from J.M.R.; questionnaires were prepared by E.R.-M. and J.M.R.; interpretation of results was performed by E.R.-M., S.B., and J.M.; article was prepared by E.R.-M. with support from the rest of the authors; final approval of the article was by all the authors; project administration was by S.B.; and acquisition of funds was by S.B. and J.M.R.

Author Disclosure Statement

No competing financial interests exist.

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Address correspondence to:
Soledad Ballesteros, PhD
Studies on Aging and Neurodegenerative Diseases Research Group
Department of Basic Psychology II
Facultad de Psicolog´ıa
Universidad Nacional de Educación a Distancia (UNED)
Juan del Rosal 10
Madrid 28040
Spain

E-mail: mballesteros@psi.uned.es