INNODOCT 2019
Valencia, 6th-8th November 2019
DOI: http://dx.doi.org/10.4995/INN2019.2019.10219

Training the working memory in older adults with the "Reta tu Memoria"[1] video game

Diana Ximena Puerta-Cortés[a], Jennifer Karina Hernández[b], Ana María Olaya[c], José Tovar[d], Daniel Varela[e]

[a]Universidad de Ibagué, Colombia, diana.puerta@unibague.edu.co. Psychology Program Professor. Director of the Education, Health and Society Research Group (GESS, in Spanish), [b]Universidad de Ibagué, kari_hernandez.l@hotmail.com, [c]El Tiempo Publishing House, jostov@eltiempo.com, iOS Senior Development Engineer, [d]anamariaolaya@gmail.com, [e]Universidad de Ibagué, 3220151067@estudiantesunibague.edu.co

Abstract

The objective of this study was to train the visuospatial and semantic working memory of a sample of Colombian older adults through the design of a serious game. The sample was composed of 20 older adults whose ages ranged from 50 to 77 years and showed signs of normal ageing. The sample belonged to the Edad de Oro group from the Universidad de Ibagué in Colombia. Participation in this study was voluntary, and the socio-demographic data and Mini-Mental state examination questionnaires were administered. The video game's creative process was developed over six months by a team made up of psychologists and systems engineers. The video game was created using 2D Construct3 game editor, and the use of JavaScript programming language and an advanced knowledge of HTML were required. Before training, two pilot sessions were carried out to adjust the video game structure. After that, the procedure was applied to the sample for 20 sessions. The time spent and errors made in the video game's five levels were registered. The results show values of significant effect size. In conclusion, the Latin American samples help corroborate the central training hypothesis. Training through video games leads to improved visuospatial and semantic working memory performance.

Keywords: *visuospatial working memory, semantic working memory, video game.*

[1] "Challenge your memory"

1. Introduction

The decreased birth rate and the progressive increase in life expectancy influence the population's age composition as these relatively reduce the number of younger individuals and increase the older age ranges. The percentage of older adults living in developing countries is expected to increase even more in the coming decades (United Nations, 2017). In these countries, old age is associated with less protection, greater dependency, illnesses and lack of productivity due to the restricted access to economic, social and academic benefits (Rodríguez, 2011).

Working memory is one of the cognitive processes that declines in a clear and linear way as individuals get older (Anguera, et al., 2013; Mammarella, et al., 2013). Working memory is the ability to withhold and use information to carry out complex tasks (Borella, 2017). It is characterised by various processes which depend on the type of content processed (verbal vs. spatial). Cornoldi & Vecchi (2003) developed a model comprising a basic structure and a skill used for active ageing. It showed that training working memory improves performance not only for the trained tasks (or similar work) but also for non-trained tasks (transfer effects). Memory training influences how individuals process information, allowing them to use their own resources in a more flexible way (Borella et al., 2017).

1.1 Video games for cognitive training

Video games entertain people of different ages without distinction. They simulate experiences, provide the user with information and knowledge, who at the same time decides to be actively involved in the screen of the device used. This activates the player's cognitive areas for the purposes of solving the game and allows for the development of skills and abilities that can be integrated in daily life (Perea & De la Peña, 2018).

The positive effects on cognitive functions may depend on the actions taken to develop the video game, such as tracking, storing in short-term visual memory and reacting to multiple aural and visual stimuli, which are continuously changing in time and space (Pavan et al., 2019).

According to Anguera et al. (2013), a supposed cognitive improvement mechanism through video games is provided by what is called the central training hypothesis, according to which the repeated stress in a cognitive system leads to plastic changes in its neural substrates, and therefore, results in better performance.

Younger people are the most exposed to video games in everyday life. In research, samples are formed by children (Egeland, Aarlien & Saunes, 2013) and adolescents (Nuyens et al., 2018). However, the possibility of using video games as a form of cognitive training among older adults has gained significant interest (Woods et al., 2018). Video games are an alternative to reduce cognitive impairment and improve quality of life (Maillot, Perrot & Hartley, 2012), strengthen memory capacity and improve coordination, repetition and concentration (Connolly et al., 2012).

1.2 Serious games

Serious games are intended to train and develop skills, teach or change attitudes and behaviour (Moizer, 2019). Their dynamics focus on training the individual's functions and they gradually increase in difficulty according to level so as to allow them to improve in each session, with the training of different cognitive skills as a positive outcome (Ballesteros et al., 2014). The human cognition project conducted by Lumos Lab (2019) has developed Lumosity®, an online program consisting of different games to improve cognitive flexibility, attention, processing speed, problem-solving and memory. This has become one of the best mental training platforms, available on the web and on iOS mobile devices.

Other programs involving cognitive stimulation, evaluation and neuropsychological rehabilitation are Gradior®, developed by Ides (2014) and Cogmed Working Memory Training® (Pearson, 2016), a computerised solution for attention disorders caused by a poor working memory.

The computerised programs aimed at improving cognitive skills, and memory in particular, require credit card payments and are expensive, so access is restricted for individuals with limited economic resources. Furthermore, despite developing countries' attempts to bridge the digital divide, this is ongoing due to restricted access to digital infrastructures, unaffordable services and the limited use of ICT (Cabrera, Orioy & Gabarró, 2018). Course offerings for older adults to learn how to use ICT is scarce, and some of these individuals are resistant to change and prefer not to use technological resources. Accordingly, this study intends to train the visuospatial and semantic memory in a sample of Colombian older adults through the design of a serious game.

2. Method

2.1 Participants

The non-probabilistic sample was formed by 34 participants whose ages ranged from 50 to 77 years who belonged to the Edad de Oro group from the Universidad de Ibagué in Colombia. 20 of them met the following inclusion criteria of the sample: at least 50 years old, ageing normally, having neither a neuropsychological nor medical history. It was a minimal risk study which met the American Psychological Association's ethical standards for research with human beings and participants signed the informed consent.

2.2 Instruments

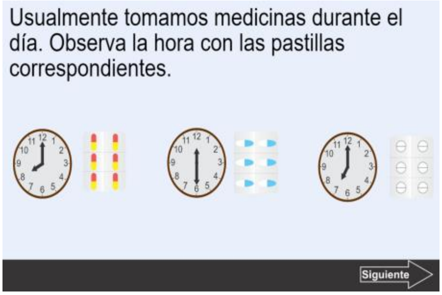
Mini-mental state examination. This examination was developed by Folstein, Folstein, McHugh and Fanjiang (2001), adapted to Spanish by Lobo, Saz and Marcos (2002). It assesses the patient's level of cognitive state in the following areas: temporal and spatial awareness, fixation capacity, attention, calculation, memory, naming, repetition and comprehension, reading, writing and drawing.

2.3 Procedure

2.3.1 Video game design

The "Reta tu Memoria" video game, designed for this project, was developed using the 2D CONSTRUCT3 framework or game editor based on HTML5 and developed by Scirra (2011). It requires the JavaScript programming language and advanced knowledge of HTML, which allows it to work on any platform (see figure 1). It was based on memory stimulation divided into five levels. The first two levels train the semantic working memory, while levels four and five train the visuospatial working memory (see figure 2 y 3).

Figure 1. Home page



Figures 2 y 3. Nivel 4 visuospatial working memory

2.3.2 Procedure implementation in the sample

The sample was screened by applying the Mini-Mental instrument to all participants; those who showed signs of cognitive impairment were excluded from the study. Eight days after applying the questionnaire, two sessions were conducted in order for participants to adapt to the use of technological tools (keyboard, mouse) and the video game conditions (home, instructions, help and levels). In all, 20 training sessions were conducted with variable periods between each session in accordance with the participant and the achievements attained. The time, errors and help at each level of the video game were recorded while it was played (see figure 4).

Figure 4. Training session. Fuente: Varela, D. (2018)

3. Results

The time and errors recordings were analysed. Due to the few help requests at each video game level, only the first two records were taken into account. Results show that the time at level two of the video game equivalent to semantic memory training was the highest. The average execution time of all sessions was 26.29 minutes, while the fifth level of training in visuospatial memory had the lowest total training time: 16.83 minutes.

The average performance rate was compared for each level between the video game's first and last training sessions. A decrease in the execution time could be observed at all levels. The average length of level one, first session, was 53.13 minutes while the final session lasted 2.73 minutes. At level two, the first session took 53.73 minutes while the duration of the last one was 3.16 minutes. Level three showed an average time of 1.85 minutes in the first session, and at the end of training, it was a minute. The fourth level had an average initial time of three minutes and ended with 2.22 minutes, while the fifth session started with 2.97 minutes and ended with 1.65 minutes. In the first three sessions, the participants finished the video game in approximately 114.68 minutes and the last two took them 10.76 minutes.

According to the errors made at each level, we found that most of them occurred in levels one and two, and level five showed the least amount of errors. Levels 1 and 2 had the highest average of errors, although there was also a significant decrease in subsequent sessions in relation to the remaining levels. At levels 1 and 2, corresponding to semantic memory, a longer execution time and higher number of errors were observed. However, throughout the training sessions, the time spent and errors made were significantly reduced. The same trend was found at levels 3, 4 and 5, regarding visuospatial working memory. Nevertheless, differences were smaller between time and errors in the initial and final sessions. The training effect size was $d = -0.82$, thus indicating a large effect in training semantic and visuospatial working memory through the video game "Reta tu Memoria."

4. Discussion

This study aimed to train the visuospatial and semantic working memory of a sample of Colombian older adults through the design of a serious game. Results show improved execution of the semantic and visuospatial working memory in the study sample. However, in the initial sessions, greater deficits of semantic memory were identified compared to the visuospatial working memory, together with further progress during the final sessions.

Levels one and two of the video game involved memorising pictures of faces, their names and then recalling or associating them again when the video game required. The semantic memory consisted of the language knowledge and learning to understand the dialect spoken, written and read, for the purposes of being able to communicate and transfer knowledge for different activities, with increasing degrees of complexity when trained in connection to language, associated with academic life, and other stimuli experienced by individuals throughout their lives (Garín & Cañas, 2017).

Levels three, four and five required locating elements in the virtual space based on memorisation and subsequently evocating visual materials, shapes and colours. The visuospatial memory was trained, which required locating the objects in space and remembering their position (Pérez, Mammarella, Del Prete, Bajo & Cornoldi, 2014). This type of working memory is used when creating and using mnemonics of visual images. It is important for geographic orientation and planning of spatial tasks. As stated above, the characteristics of visual pictures, colours, shapes and locations helped to respond to training (Cornoldi & Vecchi, 2003).

The individuals taking part in memory trainings improve the execution perception during the sessions and show a remarkable decrease in the subjective complaints made (Montejo, Montenegro & Sueiro, 2012). The video game "Reta tu Memoria," designed according to the culture, traditions and idioms of a particular social group (Garín & Cañas, 2017) was well suited for a group of older adults to use technology and it contributed to minimising the effects of ageing in the working memory (Mammarella, et al., 2013). The efficiency of this type of training through a video game confirms the hypothesis of central training: thatt the repeated stress of a cognitive system (memory) generated by training, prompts neuroplasticity and is demonstrated in training improvements (Anguera et al., 2013).

The video game's development has a technological readiness level of 6. In other words, it is possible to have a pilot prototype capable of developing all the functions required within a specific system, having passed feasibility tests in operating or actual functioning conditions. Nevertheless, documents are scarce and it has not reached the pre-commercial phase yet. The game's graphic design and data storage must continue to be improved.

The study has two limitations to be perfected in future research: the inclusion of an actively trained control group and the incorporation of follow-up sessions to determine whether the effects are stable over time or not. Despite these limitations, data showed that the video game "Reta tu Memoria" at its TRL6 stage is a cognitive strategy that contributes to the research and application areas with samples of limited technological access and to bridging the technological divide between generations, allowing older adults to train their memory by playing and to resolve their daily needs.

5. Conclusions

Working memory is one of the cognitive abilities that is most weakened due to age, training through computerized tasks such as video games, in its classification of serius games, allow developing skills through play and interaction. These tasks motivate the learning, the participant improves his performance by the feedback of his advances or failures, and experiences the virtual reality in a simulated situation.

The video game "Reta tu Memoria" allowed the repetition of tasks through different levels of semantic working memory and visospatial working memory, achieving indirect stimulation in their neuroplasticity, this was evidenced by the improvement in memory through training sessions. This type of intervention reduces the barriers between new technologies and older adults and improves their cognitive conditions.

Acknowledgments

This work was supported by Universidad de Ibagué project reference 16-445-SEM.

References

Anguera, J., Boccanfuso, J., Rintoul, J., Al-Hashimi, O., Faraji, F., Janowich, J., Kong, E., Larraburo, Y., Rolle, C., Johnston, E., & Gazzaley, A. (2013). Video game training enhances cognitive control in older adults. *Nature,* 501, 97-101.https://doi.org/10.1038/nature12486

Ballesteros, S., Mayas, J., Prieto, A., Toril, P., Pita, C., Ponce de León, L., Reales, J.M., & Waterworth, J. A. (2014). A randomized controlled trial of brain training with non-action video games in older adults: results of the 3-month follow-up. *Frontiers in Aging Neuroscience*, 7 (45), 1-12- doi: 10.3389/fnagi.2015.00045.

Borella, E., Carbone, E., Pastore, M., De Beni, R., & Carretti, B. (2017). Working Memory Training for Healthy Older Adults: The Role of Individual Characteristics in Explaining Short- and Long-Term Gains. *Frontiers in Human Neuroscience*, 11 (99), doi: 10.3389/fnhum.2017.00099.

Cabrera, P., Oriol, J., & Gabarro, P. (2018). Telecommunications Governance: Toward the Digital Economy. Inter-American Development Bank. Disponible en: https://publications.iadb.org/en/telecommunications-governance-toward-digital-economy.

Connolly, T., Boyle, E., MacArthur, E., Hainey, T., & Boyle, J. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, 59 (2), 661-686. https://doi.org/10.1016/j.compedu.2012.03.004.

Cornoldi, C., & Vecchi, T. E. (2003). Visuo-Spatial Working Memory and Individual Differences. Hove: Psychology Press.

Egeland, J., Aarlien, A. K., & Saunes, B.-K. (2013). Few effects of far transfer of working memory training in ADHD: A randomized controlled trial. *PLoS ONE, 8*(10). Article ID e75660.

Fernandez, R., & Lima, I. (2016). Cognitive Training in the elderly and its effect on the executive functions. *Acta Colombiana de Psicología*, 19(2), 177-197.

Garín, M., & Cañas, J. (2017). Entrenamiento de la memoria en adultos mayores en Tuxtla. *Lacandonia: Revista de ciencias de la UNICACH*, 3 (2), 5-14.

Ides (2014). Gradior. Inovación social & tecnologías asistenciales. Disponible en http://www.ides.es/gradior

Lumos Lab (2019). Lumocity. Disponible en https://www.lumosity.com/es/

Maillot, P., Perrot, A., & Hartley, A. (2012). Effects of interactive physical-activity video-game training on physical and cognitive function in older adults. Psychology and aging. *American Psychological Association*, 27 (3), 589-600. doi: 10.1037/a0026268

Mammarella, I. C., Borella, E., Pastore, M., & Pazzaglia, F. (2013). The structure of visuospatial memory in adulthood. *Learning and Individual Differences*, 25, 99-110. doi: 10.1016/j.lindif.2013.01.014

Moizer, J., Lean, J., Dell'Aquilab, E., Walshc, P., Keary, A…, Sica, L. (2019). An approach to evaluating the user experience of serious games. *Computers & Education,* 136, 141-151. https://doi.org/10.1016/j.compedu.2019.04.006

Montejo, P., Montenegro, M., & Sueiro, M. J. (2012). The Memory Failures of Everyday (MFE) test: Normative data in adults. *Spanish Journal of Psychology*, 15 (3), 1424-1431. https://doi10.5209/rev_SJOP.2012.v15.n3.39426.

Nuyens, F.M., Kuss, D.J., Lopez-Fernandez, O., & Griffiths, M. D. (2019). The experimental analysis of non-problematic video gaming and cognitive skills: A systematic review International. *Journal of Mental Health and Addiction*, 17 (2), 389-414. https://doi.org /10.1007/s11469-018-9946-0.

Pearson (2016). Cogmed Working Memory Training. Disponible en: https://www.cogmed.com/program

Papalia, D., Duskin, R., & Martorell, G. (2012). *Desarrollo Humano*. México: Mc Graw Hill.

Perea, M., & de la Peña, C. (2018). Influencia de los videojuegos comerciales en procesos neuropsicológicos en estudiantes universitarios. *ReiDoCrea*, 7, 55-62.

Pavan, A., Hobaek, M., Blurton, S. P., & Contillo, A., Ghin, F., & Greenle, M. W (2019). Visual short-term memory for coherent motion in video game players: evidence from a memory-masking paradigm. *Scientific Reports,* 9 (6027). https://doi10.1038/s41598-019-42593-0.

Woods, A., Cohena, R., Marsiskea, M., Alexanderb, G. E., Czajac, S. J., & Wud,S. (2018). Augmenting cognitive training in older adults (The ACT Study): Design and Methods of a Phase III tDCS and cognitive training trial. *Contemporary Clinic*al *Trials* 65, 19-32.