“EXERCISING COGNITIVE FUNCTIONS IN OLDER ADULTS VIA VIRTUAL REALITY AND GAMING TECHNOLOGY: A PRELIMINARY STUDY COMPARING TWO INTERVENTION PROGRAMS”

Bapka, V.¹, Bika, I.¹, Savvidis, T.¹, Konstantinidis E. I.¹, Moraitou, D.¹, Bamidis, P.¹, & Papantoniou, G.²

¹ Aristotle University of Thessaloniki
² University of Ioannina

ARISTOTLE UNIVERSITY OF THESSALONIKI, HELLAS & OPEN CARE CENTER FOR THE ELDERLY OF PYLAIA & KALAMARIA, THESSALONIKI, HELLAS

10TH PANHELLENIC CONFERENCE ON ALZHEIMER’S DISEASE & RELATED DISORDERS CONDUCTED ALONG WITH THE 2ND MEDITERRANEAN CONFERENCE ON NEURODEGENERATIVE DISEASES
INTRODUCTION

- Increasing life’s expectancy
  - 1950 → 65 years
  - 2045-2050 → 83 years (United Nations Organization, 2013)

- Research is now focused on the improvement of life’s quality in third age (Kunlin Jin, et al., 2015; Restrepo & Rozental, 1994)
  - Maintenance of cognitive function (Craik & Bialystok, 2006)

- Normal aging → 6th - 7th decade of life → Age-Related Cognitive Decline (A.R.C.D.) (Bischkopf, Busse, & Angermeyer, 2002)
  - memory (working memory)
  - executive functions (inhibition, switching) (Schaie, Willis, & O’Hanlon, 1994)

- Individual differences (Park, O’Connell, & Thomson, 2003; Ylikoski et al., 1999)
Brain’s Plasticity

- Brain’s ability to adopt in environmental circumstances by changing its structure (Lövdén, Wenger, Mårtensson, Lindenberger, & Bäckman, 2013)
- A.R.C.D could be delayed or even averted by appropriate practice and therapeutic intervention, which are attributed to brain’s plasticity (Green & Bavelier, 2008)
  - Engvig et al. (2010): healthy elderly people have been intensively practiced in memory strategies → improved performance, increased density in the right tapered helical and orbitofrontal cortex
  - Lövdén, Brehmer, Li, & Lindenberger (2012): the elderly have been practicing in virtual navigation in treadmills for 4 months → stable hippocampal volume in association to control group, where a decrease was observed

✔ Target: change in brain’s structure by mobilizing and activating latent areas through cognitive training
Cognitive Empowerment Interventions

Effectiveness:

- Improvement of healthy elderly people’s cognitive function (Ball, Berch, Helmers, et al., 2002; Mahncke, et al., 2006; Smith, et al., 2009) → maintenance > 5 years (Willis, Tennstedt, Marsiske, & et al., 2006)

- Decrease in memory loss of dementia (Valenzuela & Sachdev, 2009).

✓ Possibility to perform cognitive interventions by using cutting edge technology

- Video Games (VG)
- Virtual Reality programs (VR)
1. Video Games

- Exposure to various stimuli depending on game’s category (strategy, action, first person, etc.)

- **Basak, Boot, Voss & Kramer (2008):** checked whether there was an improvement of higher cognitive functions after training 40 elderly people to the strategy game “Rise of Nations” for 23.5 hours
  - Improved performance in switching tasks, short term visual memory, working memory and mental rotation

- **Van Muijden, Band & Hommel (2012):** trained healthy elderly people by using VG
  - Small improvement in general executive functions

- **Zhang & Kaufman (2015):** tried to improve balance, mobility, executive functions and processing speed on the elderly
  - The elderly were just as capable as younger people at learning and adjusting in new environments (plasticity in the Third Age)
2. **Virtual Reality**

- High level computer interface, which includes real time simulation and interactions through multiple sensory pathways (Burdea, 2003; Anat Mirelman et al., 2010).

- Virtual reality as cognitive rehabilitation tool → Innovative practice, which uses computer software in order to combine visual, auditory and tactile sensations, as simulation of different aspects of everyday life (Rose, Attree, Brooks, & Andrews, 2001)

- **Kizony et al. (2012)**: training through learning metacognitive strategies in a virtual Super-Market
  - 7 elderly people with Mild Cognitive Impairment (M.C.I.)
  - 10 therapeutic sessions/ 5 weeks
  - Measuring cognitive abilities: before, during and after the intervention

- 4/7 participants improved their executive functions
- Intervention’s benefits were maintained to alternative frameworks
CURRENT RESEARCH’S GOAL

- Whether **VG** and **VR** programs are effective as cognitive training tools to the community dwelling elderly
HYPOTHESES OF THE RESEARCH

1. Video games’ intervention is expected to improve elderly people’s performance in cognitive tests and this performance would be maintained in the follow-up measurement.

2. Virtual reality’s intervention is expected to meliorate elderly people’s cognitive function and this improvement is going to be maintained for at least 1 month.

3. It is expected that the elderly, who have joined the VR’s program, would do better than the elderly, who have been trained by playing VG.
METHOD

PARTICIPANTS

1st Group: Video Games’ Intervention (Super Mario Kart)

- $N = 9$
- Age: Range $= 65-78$ years, $M = 71,33$, $SD = 4,60$
- Gender: Male $= 4$ (44,4%) & Female $= 5$ (55,6%)
- Educational level:
  - Low (0-9 years of schooling) $= 8$ (88,91%)
  - Middle (10-12 years of schooling) $= 1$ (11,1%)
- GDS-15: $M = 0,77$, $SD = 1,39$
- MMSE: Range: $27-30$, $M = 28,88$, $SD = 1,05$
- MoCA: Range: $22-28$, $M = 25,11$, $SD = 2,75$
2nd Group: Virtual Reality’s Intervention

- $N = 10$
- Age: Range = 65-79 years, $M = 70.3$, $SD = 5.03$
- Gender: Male = 6 (60%) & Female = 4 (40%)
- Educational level:
  - Low (0-9 years of schooling) = 4 (40%)
  - Middle (10-12 years of schooling) = 3 (30%)
  - High ($\geq$13 years of schooling) = 3 (30%)
- GDS-15: $M = 0.90$, $SD = 1.10$
- MMSE: Range: 27-30, $M = 28.70$, $SD = 1.15$
- MoCA: Range: 22-29, $M = 26$, $SD = 2.16$
PARTICIPANTS

Total sample
(N=19)

Video Game
(N=9)

Virtual Reality
(N=10)

- Age: $\chi^2(10)=.921, p>.05$
- Gender: $\chi^2(1)=.656, p>.05$
- Educational level: $\chi^2(2)=.092, p>.05$
INSTRUMENTS

Preliminary examination

1. Geriatric Depression Scale (GDS-15) → screening test
2. Mini Mental State Examination (MMSE) → screening test
3. Montreal Cognitive Assessment (MoCA)
1. **D-KEFS Color-Word Interference test (C- WIT)** *(Delis, Kaplan, & Kramer, 2001)*

- **Condition 1:** Naming the 3 basic colors (till 90”) → **speed of naming**
- **Condition 2:** Reading words, written with black ink, which refer to colors (till 90”) → **reading speed**
- **Condition 3:** Naming the color of the ink that words are written, while words refer to colors (till 180”) → **verbal inhibition**
- **Condition 4:** Naming the color of the ink that words are written and alternately reading words that refer to colors (till 180”) → **cognitive flexibility (inhibition/switching)**
2. D-KEFS Design Fluency Test (D.F.T.)

(DeLis, Kaplan, & Kramer, 2001)

- Creation of different patterns by connecting the spots using 4 straight lines within 60”
- Condition 1: Filled dots (60”) → non verbal creativity/visual attention, processing speed, drawing skills
- Condition 2: Empty dots only (60”) → high level inhibitory control
- Condition 3: Dot switching (60”) → cognitive flexibility (inhibitory control and switching), simultaneous processing
3. **D-KEFS TOWER TEST (TT)**

*(Delis, Kaplan, & Kramer, 2001)*

- Goal → Construction of appointed «towers», through moving disks varying in size across three pegs in the fewest number of moves by following two rules

- **9 problems:**
  - 1-3 → 30”
  - 4 → 60”
  - 5-6 → 120”
  - 7 → 180”
  - 8-9 → 240”

- Visual- spatial planning, learning rules, inhibitory control, working memory
4. **Visual Patterns Test (V.P.T.)**

*(Della Sala, Gray, Baddeley, & Wilson, 1997)*

- Presentation of some cards, which have patterns like chess for 3”, memorization and reproduction in a plain plexus
- Gradual increase in the complexity of patterns
- Interruption after 3 consecutive errors in the same level of difficulty
- **Visual working memory**

*Fig. 1. Examples of simple and complex matrix patterns from the Visual Patterns Test.*
INTERVENTION PROGRAMS

1. Video Game (Super Mario Kart)

- Equipment: Wii console (central processing unit, wireless remote control - steering wheel, screen 26”)
- Participants were seated in front of the screen and they were holding the steering wheel
- They were supposed to finish the track by driving a car, while trying to beat their opponents
- Customized intervention
- 18 Sessions
- Training duration: 40 minutes/ 12 tracks

- Attention, visual memory, executive functions
2. Virtual reality program (Fit For All)

- Designed by the Department of Medical Physics Laboratory of A.U.TH.
- Equipment: screen 32”, Kinect sensor (motion detector), laptop
- Participants were standing in a 2-meter distance in front of the screen and the sensor
- 18 Sessions
- Training duration: 40 minutes/4 tasks
Consists of 4 tasks:

1. Apple collection using only the right hand
   - 1<sup>st</sup> Condition: attention (5’) ➔ collects every apple that appears on the tree in succession
   - 2<sup>nd</sup> Condition: inhibition (5’) ➔ for each apple that appears on screen, a rotten one appears too, and the participant has to avoid collecting it
   - 3<sup>rd</sup> Condition: switching & inhibition (5’) ➔ two types of apple (red - green) appear on screen, and the participant has to collect them alternately

2. Fish collection by moving the torso back - forth
   - 1<sup>st</sup> Condition: attention (5’) ➔ collects each fish that appears on screen
   - 2<sup>nd</sup> Condition: inhibition (5’) ➔ avoids the sharks that appears between the fish that he/she is collecting
3. **Golf simulation by moving the torso in 4 directions (back-forth- left - right)**

   - 1\textsuperscript{st} Condition: **attention** (5’) \(\rightarrow\) throws the ball in a hole that exists on screen
   - 2\textsuperscript{nd} Condition: **inhibition** (5’) \(\rightarrow\) throws the ball in the hole by avoiding the pothole that appears

4. **Break Blocks Game simulation by moving the torso right- left**

   - By moving his/her torso the participant moves the bar so that to hit the ball and break the bricks (5’) \(\rightarrow\) **attention**
PROCEDURE

- Customized examination:
  - The 1\textsuperscript{st} Intervention group examined in Open Care Center for the Elderly in Pylaia, Thessaloniki
  - The 2\textsuperscript{nd} Intervention group examined in Open Care Center for the Elderly in Kalamaria, Thessaloniki

- Battery administration:
  - Before the intervention (before)
  - Right after the intervention (after)
  - 1 month after the intervention (follow up)
  - Before the start of each intervention program, participants were trained in order to become acquainted with the tasks (1 session)
SEQUENTIAL ADMINISTRATION OF INSTRUMENTS
RESULTS

Statistical Analyses (SPSS v.22)

To find quantitative differences between the 3 measurements and the two groups:

- Mixed Repeated Measures ANOVAs
  1. between-subjects factor = group type (VG-VR)
  2. within-subjects factor = measurements of the test (before- after- follow up)
RESULTS

D- KEFS Color-Word Interference Test (C-WIT)

- Inhibition and switching (non-corrected errors) → before vs. follow up

\[ F(1.33, 22.64) = 6.948, \ p = .010, \ \eta^2 = .290 \]

Before - follow-up → \( p = .029 \)
RESULTS

- **D-KEFS Design Fluency Test (D.F.T.)**
  - **Inhibition (empty dots only) →** before vs. after & follow up
    
    \[ F(2,34) = 7.672, \ p = .002 \ \eta^2 = .311 \]
    
    Before- after \( \rightarrow p = .011 \)
    
    Before- follow-up \( \rightarrow p = .007 \)

- **Video games:** before vs. after
  
  Before- after \( \rightarrow p = .012 \)

- **Virtual reality:** before vs. follow up
  
  \[ F(2,18) = 24.100, \ p = .009, \eta^2 = .411 \]
  
  Before- follow-up \( \rightarrow p = .017 \)
RESULTS

- **D-KEFS Design Fluency Test (D.F.T.)**

  - Executive functions (total scores in 3 conditions) → before vs. after & follow-up

    \[ F(1.44, 24.46) = 9.670, \ p = .002, \ \eta^2 = .363 \]

    Before- after → \( p = .006 \)
    Before- follow-up → \( p = .011 \)

  - Video games → before vs. after

    \[ F(2, 16) = 3.863, \ p = .043, \ \eta^2 = .326 \]

    Before- after → \( p = .056 \)

  - Virtual reality → before vs. follow up

    \[ F(2, 18) = 7.855, \ p = .004, \ \eta^2 = .466 \]

    Before- follow-up → \( p = .037 \)
RESULTS

D-KEFS Design Fluency Test (D.F.T.)

- **Design accuracy** → before vs. after

\[ F(2,16) = 4.599, \ p = .026, \ \eta^2 = .365 \]

Before- after → \( p = .019 \)
RESULTS

**D-KEFS Tower Test (TT)**

- **Accuracy of movements** → before vs. after & follow up

\[ F(2,34) = 7.731, p = .002, \eta^2 = .313 \]

Before- after \( p = .005 \)
Before - follow-up \( p = .017 \)

**Video games** → before vs. after & follow up

\[ F(1.3,10.47) = 9.822, p = .007, \eta^2 = .551 \]

Before- after \( p = .000 \)
Before - follow-up \( p = .022 \)
RESULTS

- **D-KEFS Tower Test (TT)**
  - **Total score** → before vs. after & follow up
    - $F(1.6, 26.9) = 9.969, p = .001, \eta^2 = .370$
    - Before- after $p = .052$
    - Before- follow-up $p = .002$

- **Video games** → before vs. follow up
  - $F(2, 16) = 5.209, p = .018, \eta^2 = .394$
  - Before- follow-up $p = .052$

- **Virtual reality** → before vs. follow up
  - $F(1.36, 12.2) = 5.066, p = .035, \eta^2 = .360$
  - Before- follow-up $p = .056$

Graphs showing estimated marginal means of total scores for video game and virtual reality interventions.
RESULTS

Visual Patterns Test (V.P.T.)

Visual Working Memory (raw scores) \( \rightarrow \) before vs. after & follow up

F(2,34) = 14.302, \( p = .000 \), \( \eta^2 = .038 \)

- Before – after \( \rightarrow p = .000 \)
- Before - follow up \( \rightarrow p = .005 \)

Video games \( \rightarrow \) before vs. after & follow up

F(2,16)=11.829, \( p=.001 \), \( \eta^2=.597 \)

- Before – after \( \rightarrow p = .007 \)
- Before - follow-up \( \rightarrow p=.014 \)

Virtual reality \( \rightarrow \) before vs. after

F(2,18)=5.307, \( p = .015 \), \( \eta^2 = .371 \)

- Before – after \( \rightarrow p = .008 \)
DISCUSSION

- **VG** was effective in planning and visual working memory
- **VG** improved inhibition and cognitive flexibility, but the effect was not maintained ➔ have to keep playing in order to maintain the effect
- **VR** was effective in inhibition, accuracy, cognitive flexibility and planning
- **VR** improved visual working memory but the effect was not maintained
REFERENCES


