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Cognitive Benefits of the Attentional vs Exergame Training in older Adults

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ABSTRACT

Objective: the present study aimed at comparing the effectiveness of an Attentional Computerized Cognitive Training and a commercial Exergame Training.

Methods: eighty-four healthy older adults took part in the study. They were randomly assigned to one of the following conditions: Attentional Computerized Cognitive Training (ATT-CCT), Exergame Training (EXERG-T), or passive Control Group (CG). Participants assigned to the experimental groups underwent 8 laboratory-based sessions - lasting approximately 45 minutes each – of the respective training activity. A battery of cognitive tests was assessed before, after, and 3 months following the intervention phase.

Results: the results showed that just the ATT-CCT improved participants' performance, specifically within attention, processing speed, verbal learning and memory. While both intervention groups revealed improved memory self-perception and decreased self-reported absent-mindedness, only the benefits following the ATT-CCT proved to be stable over time.

Conclusions: the results suggested that our ATT-CCT may be an effective tool for enhancing cognitive abilities in older healthy adults.

Keywords: Attentional Computerized Training, Exergame, Cognitive Training, Aging

Introduction

Aging is a highly complex and – up to this time – not fully understood process. Available evidence indicates that not all cognitive functions follow the same pattern of age-related decline (Heilman & Nadeau, 2019). Processes such as speed of processing, working memory, and encoding new information into episodic memory are classified as those that tend to decline steadily over the human lifespan, starting as early as in the age of 20 (Hedden & Gabrieli, 2004).

Even though current evidence suggests that there is no single, isolated factor primarily responsible for cognitive alterations following the aging process (Park & Reuter-Lorenz, 2009), some cognitive functions have been designated as predominantly accountable for the deficits. The attentional system is frequently suggested as a central factor in the genesis of general cognitive decline following the aging process (Sperduti et al., 2016; Sylvain-Roy et al., 2015). The attentional system is responsible for filtering the stream of information from the external and internal environment, it protects us from experiencing a constant cognitive overload caused by the multitude of stimulations we are exposed to each day (Leclercq & Zimmermann, 2004). Consequently, it is crucial for the proper functioning of other mental processes. While the capacity to perform simple attentional tasks requiring, e.g., immediate repetition of a string of digits, is thought to be maintained at a stable level across the lifespan, more challenging tasks involving divided attention or task-switching are characterized by age-related decline (Heilman & Nadeau, 2019; Robertson & Dockree, 2019). The interrelatedness of attention and other, higher cognitive processes has been broadly studied. Selective attention – the ability to choose a given, relevant stimulus while ignoring the competing ones – is crucial for memory encoding (Ravizza & Conn, 2022). The overlap between the attentional system and executive functions is also well known (Cohen, 2014; Sohlberg & Mateer, 2001). In order

to program, plan, and monitor one's behaviour it is imperative to maintain the salience of an overreaching goal. The involvement of sustained attention seems to be crucial (Robertson & O'Connell, 2014). The choice of which information is important for the pursued goal, for its part, is possible because of the recruitment of the executive control of attention (Miller & Buschman, 2014).

This strong interdependence of attention and other higher cognitive processes makes it difficult to fully understand the nature of age-related changes in the attentional system. Nonetheless, a growing body of evidence suggests that attention, despite its fragility, presents significant capacity for plastic reorganization (Robertson & O'Connell, 2014) and therefore it is possible to mitigate the negative effects of age on the attentional domain (Robertson & Dockree, 2019; Zanto & Gazzaley, 2014).

Over the past years, traditional cognitive interventions are slowly being replaced by computerized methods. They have several advantages over the conventional ones. Computerized cognitive training (CCT) has the potential to be widely available to the public, as it does not necessarily require face-to-face interaction nor physical presence of a therapist. It does not involve the necessity of finding a convenient meeting location, since it can be performed anyplace, nor does it entail troublesome travels. As a consequence, computer-based cognitive interventions are now being considered as a more cost-effective alternative to traditional brain training methods (Kueider et al., 2012). However, the results of research investigating the effectiveness of CCT on cognitively healthy older adults remain unclear (Bonnechère et al., 2020; Lampit et al., 2014; Shah et al., 2017), It is partially due to significant methodological differences between the studies and varying theoretical approaches. Factors such as the type of cognitive processes assessed, the chosen evaluation methods, specific characteristics of the game/tasks used, and features of the intervention regimen (i.e. intensity and frequency of sessions, duration

of a single session, an individual or a group practice) are often being overlooked (Toril et al., 2014).

Recently, exergaming – an interactive form of exercising – has gained consideration as an enjoyable and motivational tool to improve both physical and cognitive health. Exergaming offers the possibility to combine motor exercise with cognitive activities. It has been investigated as a potential training for active aging (Moret et al., 2022) and it was found to improve cognitive functions (Kayama et al., 2014; Maillot et al., 2012; Schoene et al., 2013), voluntary step execution (Pichierri et al., 2012) and general quality of life in elderly (Law et al., 2014). A recent systematic review (Stojan & Voelcker-Rehage, 2019) reported a total of 14 out of 15 studies demonstrated beneficial effects of exergaming with heterogeneous findings on cognitive domains and a slightly superior benefit on executive functions in healthy older adults (>60 years). These results suggest that exergame systems might be a promising approach to preserve and improve mental health in healthy older adults.

So far, the evidence for efficacy of computer-game based cognitive intervention programs in older adults remains inconclusive, especially with regard to the generalization effect to day-to-day functioning.

In this paper we aimed at investigating the cognitive effects following the ad hoc Attentional Computerized Cognitive Training (ATT-CCT) and the off-the-shelf Exergame Training (EXERG-T) through their comparison. On the one hand, the single-domain of attention has been chosen as the primary focus of the "ad hoc" attentional training procedure as it is known to be a fundamental block of human cognition (Mayas et al., 2014). On the other hand, the exergame employed in the present study, which is a commercial exergame aiming at reinforcing mental abilities, engages multiple domains in the training activity. In this regard, it is claimed that this multi-domain stimulation is a

better representation of real-life demands (Green & Bavelier, 2008). Previous studies provide some evidence for the effectiveness of multi-domain training in enhancing older adults' cognition (Gallou-Guyot et al., 2020).

Based on previous findings we expected both intervention programs to yield positive effects. Our hypothesis was that repetitive stimulation of the attentional system by the employed ATT-CCT would elicit positive changes not only within the trained domain, but it would also result in the transfer effect to other cognitive abilities and measures of perceived everyday functioning. In line with the assumption, it has been shown there are some core cognitive abilities whose improvement leads to enhanced performance in other cognitive domains and daily functioning (Cheng et al., 2018). At the same time, we expected the EXERG-T to produce broad, yet less prominent positive changes in older adults' cognition since it is an entertainment game. Additionally, we aimed to investigate whether the observed improvements would be maintained over time, following a 3-month no-contact period. We measured participants' performance on a series of cognitive tests assessing several cognitive functions such as attention, processing speed and memory. To evaluate the impact of the training regimens on older adults' day-to-day functioning, we collected self-reported ratings of everyday cognition.

Materials and Methods

Participants

The recruitment phase involved various strategies: an advertisement providing brief introduction of the planned research activities has been promoted at the "Ufficio Attività Creative per la terza età – Comune di Padova" (Service for the Elderly of the Municipality of Padova); social networks and the snowball sampling procedure have been used to reach out to as many potential participants as possible; furthermore, two researchers visited

several venues in which creative activities and courses for older adults take place in order to present the summary of the project in person.

Individuals interested in participating in the study were firstly informed about the procedure of the research through a brief telephone interview. They were further assessed ascertaining the following inclusion criteria: (a) age 65 or above; (b) no history of neurological, psychiatric or addictive disorders; (c) no severe depressive symptoms; (d) normal or corrected-to-normal hearing and vision.

None of the participants presented severe depressive symptoms (score <30), as assessed with the Beck Depression Inventory (BDI-II) (Sica & Ghisi, 2007). Cognitive reserve was assessed with the Cognitive Reserve Index questionnaire (CRIq) (Nucci et al., 2012). In total 84 older adults were enrolled in the study. Participants were randomly assigned into the three groups: 27 belonged to the ATT-CCT group, 28 to the EXERG-T group and 29 to the passive CG. Participants' characteristics, divided by group, are presented in Table 1.

TABLE 1 ABOUT HERE

Ethics

At the beginning of the study, all the participants were handed a written informed consent. The experimenters made sure that the procedure has been fully understood. Having any possible doubts and concerns explained, participants signed the document. Subsequently, a unique identification code has been assigned to each of them in order to ensure pseudonymisation of their data. All personal information of the participants was treated confidentially. Participants were informed about their right to withdraw from the study at any time.

The study was approved by the Ethics Committee of the Human Inspired Technologies Research Centre, University of Padua, Italy on the 1st of March 2019.

Study Design

This study was a randomized-controlled trial including two groups involved in parallel training interventions – the ATT-CCT group and the EXERG-T group, and a passive CG. The current study focuses on the comparison of the effects of an "ad hoc" Attentional CCT and off-the-shelf Exergame Training on cognitive abilities and the perceived daily functioning of older adults.

All the participants completed a baseline cognitive assessment.

The following tests were administered:

- Digit Span task (Orsini et al., 1987). Two versions of the task: Digit Span Forward (DS-F) and Digit Span Backward (DS-B);

- Symbol Digit Modalities Test (SDMT) (Nocentini et al., 2006). The oral version of the test was administered.

- Verbal Selective Reminding Test (VSRT) (Buschke & Fuld, 1974). Two alternative forms of the Italian version of the test have been utilized. Three sub-scales were considered: SRT- Long-Term Storage (SRT-LTS), SRT - Consistent Long-Term Retrieval (SRT-CLTR) and SRT- Delayed Recall (SRT-D).

- Cognitive Failure Questionnaire (CFQ) (Broadbent et al., 1982). It is used to evaluate the effectiveness of intervention on participants' perceived deficits in cognitive processes in daily life.

After the baseline assessment individuals assigned to the ATT-CCT group or EXERG-T group underwent 8 laboratory-based sessions of their respective training activity. Each of the sessions lasted approximately 45 minutes. The meetings took place 2 to 3 times a week (depending on participants' availability) at the Department of General Psychology at the University of Padova. Throughout the intervention period, the CG was asked to follow their usual daily routine.

All participants, regardless of their group assignment, were assessed for the second time following the intervention phase (or a respective period of 4 to 5 weeks). The same battery of tests as in the baseline evaluation was used. Alternative (A/B) version of the VSRT memory subtests was used.

Individuals assigned to the ATT-CCT group and EXERG-T group underwent additional testing session after a 3-month follow-up period. As a result of the national lockdown imposed by the Italian government on the 9th of March 2020, which was caused by the outbreak of CoVid-19 pandemic, 3 participants assigned to the ATT-CCT group underwent the follow-up assessment with a 3-month delay, thereby completing it after a 6-month no-contact period. For the same reason, 5 participants belonging to the EXERG-T group did not complete the follow-up assessment. Three participants assigned to the EXERG-T group dropped out due to health reasons.

Training programs

- *Attentional Computerized Cognitive Training*

The program that has been chosen as the training activity - MS-Rehab (Gaspari et al., 2017, 2020; Zini et al., 2017) is a system that can be assessed by the user through a web browser (preferably Google Chrome) using either PC or a tablet. The training was administered in small groups (not more than 4 people at a time) or individually, upon participants' request. Participants were following the training activities in presence, in a dedicated classroom at the Department of General Psychology of the University of Padua throughout the entire study procedure.

Each training session comprised four different exercises, lasting 10 minutes each. There were 4 main categories of exercises, each targeting different aspect of attentional domain (see Appendix A).

- *Exergame Training*

The Exergame Training took place in a dedicated laboratory in the Department of General Psychology, University of Padova. The room was equipped with a TV screen (LCD Samsung 40"), an Xbox-360 console and a Kinect device supplied with sensors able to recognize and code participants' movements. Each participant stood approximately 2 meters away from the TV screen and the sensors and performed the training individually under the supervision of a trained research assistant. The Exergame Training (see Appendix B) consisted of 8 sessions, each of them lasted approximately 45 minutes.

Data analysis

Group differences in the sociodemographic data and baseline performance (Pre-test) were compared with a one-way analysis of variance (ANOVA) for continuous variables and Chi-square test for categorical variables.

To verify any changes over Testing session (Pre-test, Post-test, Follow-up), differences between Groups (ATT-CCT, EXERG-T, CG), and the differential impact of Group over Testing session (Group x Session), mixed-effect ANOVA model (with Restricted Maximum Likelihood - REML estimation and na.omit option, that is stripping any observations with any missing values in any variables) was used. All the assumptions required to run a mixed-effect ANOVA were fairly satisfied, as shown by "Performance" (an R package) for a visual check of model assumptions. The variables of interest were DS-F, DS-B, SDMT, SRT-LTS, SRT-CLTR, SRT-D, CFQ. For the effect size, a priori power analysis was performed using the software program G * Power 3.0.10 (Faul et al., 2009). Given an effect size Cohen's f of 0.20 corresponding to Cohen's d = 0.4, an intermediate effect size according to Cohen's (Cohen, 1988) criteria, α of 0.05 and a power of 80%, a sample size of n = 66 (a minimum of 22 per group) was determined.

Post-hoc analyses to determine single difference between changes over Testing session (Pre-test − Post-test and Pre-test − Follow-up) were performed using Student's paired t-test controlled for multiple comparisons with False Discovery Rate methods.

Effect sizes, reported as η^2_p for the ANOVA, was considered as small for η^2_p = 0.01, medium for η^2_p = 0.06, and large for η^2_p = 0.14 and above (Bakeman, 2005); effect size Cohen' *d* from t-tests, was defined as small at d = 0.2, medium at *d* = 0.5, and large at *d* = 0.8 and above (Cohen, 2013).

Statistical analyses were performed in R environment (Team, 2015) using the "lmerTest" (Kuznetsova et al., 2017) and "MuMIn" packages (Barton, 2014).

Results

Analysis of demographic characteristics revealed no significant differences between groups with respect to Age, $F(2, 81) = 1.29$, p = .279, Education, $F(2, 81) = 2.20$, p = .117, Sex, $X^2 = 1.21$, p = 0.545, and mood disturbance assessed using the Beck Depression Inventory (BDI-II), $F(2,81) = 1.66$, p = .195. With regard to the level of cognitive reserve, as assessed with Cognitive Reserve Index questionnaire (CRIq), $F(2, 81) = 3.17$, p =0,047, the CG group obtained on average a slightly lower, but still very high index of cognitive reserve (CRI) (Table 1), as compared to the other two groups. Means and standard deviations of Pre-test, Post-test, and Follow-up assessments of ATT-CCT, EXERG-T and CG group are reported in Table 2.

TABLE 2 ABOUT HERE

To assess interventions' effectiveness, a mixed-effect ANOVA model with DS-F, DS-B, SDMT, SRT-LTS, SRT-CLTR, SRT-D, CFQ as dependent variables, the Group (ATT-CCT, EXERG-T and CG) as Between-Subject factor and Testing session (Pre-test and Post-test) as Within-Subject factor, was calculated.

No significant effect was found neither for the DS-F, $F(2, 81) = 1.49$, $p = .232$, $\eta^2_p = .04$, nor for the DS-B, $F(2, 81) = 0.12$, $p = .888$, $\eta^2_p < 0.001$. Concerning the measure of information processing speed, SDMT, there was a significant main effect of Group, $F(2, 81) = 3.50$, $p = .035$, $\eta^2_p = 0.08$, of Testing session, $F(1, 81) = 24.27$, $p = .000$, $\eta^2_p = 0.23$, and the interaction Group x Testing session was also significant, $F(2, 81) = 4.86$, $p = .010$, $\eta^2_p = 0.11$ (see Table 3 and Figure 1).

TABLE 3 ABOUT HERE

FIGURE 1 ABOUT HERE

As revealed by *post-hoc* analysis with paired t-test with FDR adjusted p-value, just ATT-CCT group showed significantly better performance at Post-test when compared to Pre-test in SDMT, $t(26) = -4.6$, $p_{adj} = 0.001$, $d = -0.90$, while none of the other two groups did ($p > 0.05$) (see Table 4 and Figure 1).

Observing the outcomes for the memory tests, two out of the three dependent variables of the VSRT showed a significant Group x Testing session interaction: SRT-LTS, $F(2, 80.25) = 3.57$, $p = .033$, $\eta^2_p = 0.08$, SRT-CLTR, $F(2, 80.53) = 3.74$, $p = .028$, $\eta^2_p = 0.09$ (see Table 3).

As shown by *post-hoc* within-group comparisons with paired t-test with FDR adjusted p-value, just for the ATT-CCT group there was a significant difference between pre- and post-training measures: SRT-LTS, $t(25) = -3.67$, $p_{adj} = 0.003$, $d = -0.73$, and SRT- CLTR, $t(25) = -4.2$, $p_{adj} = 0.001$, $d = -0.84$; no significant improvement was obtained for the EXERG-T, nor for the CG ($p > 0.05$) (see Table 4 and Figure 1).

With regard to the self-rating scale of cognitive functioning (CFQ), there was a general decrease of memory and absent-mindedness complaints across Testing session, $F(1, 81)$

= 26.28, p < .001, η^2_p = 0.24 and also Group x Testing session interaction was significant, $F(2, 81) = 3.36$, p = .040, η^2_p = 0.08.

Performing *post-hoc* paired t-test analysis, both ATT-CCT group, $t(26) = -4.78$, p_{adj} =0.001, d = 0.94, and EXERG-T group, $t(27) = 2.59$, p_{adj} =0.037, d = 0.50, presented reduced subjective cognitive complaints across time, while the CG group showed stable self-perception of everyday cognition across sessions (p > 0.05) (see Table 4 and Figure 1).

TABLE 4 ABOUT HERE

To further inspect any maintenance effects in the follow-up session of the improvements previously detected, paired t-test with FDR adjusted p-value for the comparison between Pre-test and Follow-up were performed. A significant effect in all tests was obtained only for the ATT-CCT group: SDMT, $t(26) = -4.6$, p_{adj} =0.002, d = -0.68, SRT-LTS, $t(26) = -3.35$, p_{adj} =0.003, d = -0.66, SRT-CLTR, $t(25) = -4.2$, p_{adj} < .001, d = 0.79, and CFQ, $t(26) = -3.28$, p_{adj} =0.003, d = 0.64. After three months the subjective reduction of cognitive complaints for the EXERG-T group was not preserved, $t(19) = -0.04$, p = .967, d < 0.01.

Therefore, the long-lasting effects of cognitive enhancement obtained were maintained only for the ATT-CCT group across the following 3 months (see Table 5).

TABLE 5 ABOUT HERE

Discussion

The main goal of the current study was to investigate and compare the effectiveness of two types of cognitive interventions – the ad hoc Attentional Computerized Cognitive Training, and the off-the-shelf Exergame Training – in

enhancing older adults' cognitive status. Based on the results of similar studies (Bherer et al., 2008; Kramer et al., 1995; Van Vleet et al., 2016; Yang et al., 2020) it was expected that the ATT-CCT, despite its confined focus on the domain of attention, would elicit positive changes not only within the trained domain, but it would also result in the transfer effect to other cognitive functions. The EXERG-T, inversely, due to its low level of specificity and primarily entertaining function, was thought to yield broad, but small effects (Soares et al., 2021; Torre & Temprado, 2022).

With regard to the abilities directly targeted by the ATT-CCT, clear evidence for the beneficial impact of the intervention has been found only on the Symbol Digit Modalities Test. In line with our initial assumptions, the attentional training group revealed improved performance in the information speed of processing, while none of the other two groups did. Previous aging research found that processing speed is one of the most affected by age cognitive functions (Garcia-Cabello et al., 2021). It is recognised as a robust predictor of the general age-related decline (Eckert, 2011; Salthouse & Ferrer-Caja, 2003). Decreased processing speed negatively influences performance in the activities of daily living (Roye et al., 2022). Therefore, the improvement observed on the measure of processing speed for the ATT-CCT group may have important and positive practical implications.

No-training effects have been found on the second attentional measure– the Digit Span test – for the ATT-CCT group. No significant changes have been observed in the performance of the EXERG-T or the CG group either. It could be argued that the participants involved in the current study have already been functioning near their cognitive ceiling within the criterion tasks, leaving limited room for improvement.

Regarding the other cognitive function investigated, the results of the present study provide evidence for substantial improvement within the domain of verbal learning

and memory following the attention-focused cognitive intervention (ATT-CCT). It suggests superior benefits of the applied single-domain training regimen within the domain of memory with respect to the EXERG-T. This pattern of post-intervention gains highlights the crucial role of attention in enhancing other cognitive abilities. The greater memory enhancement observed in the ATT-CCT group is in accordance with the assumption that by training attentional capacities, such as focused attention and allocation of attentional resources, the process of information encoding is being facilitated and reinforced (Chambon et al., 2014). This, in consequence, promotes better retrieval.

Both of the intervention groups revealed decreased memory complaints and better self-perception of everyday functioning after the training period, while no changes for the CG group have been observed. It could be argued that the improvement in the self-reported measure of everyday cognition can be explained by the subject-expectancy effect. While it is not possible to evaluate which element of the training – the cognitive or physical stimulation itself or the awareness of being subjected to the training procedure – accounts for the observed beneficial effects, it is worth noticing that older adults tend to gradually depreciate their inner representation of memory. They are inclined to underestimate their memory abilities and exaggerate experienced difficulties (Chambon et al., 2014). Therefore, improved self-perception of one's competences has important practical implications for the older adults' sense of agency and well-being.

Finally, as indicated by the results obtained by the ATT-CCT group at 3-month follow-up, the benefits deriving from the training procedure proved to be stable and long-lasting. All the cognitive measures demonstrating participants enhanced post-training functioning, showed maintenance of good performances across testing session. The same effect was not observed for the EXERG-T group.

The present study has some strengths and some limitations that need to be addressed. Considering the novelty of the adopted training, ATT-CCT exercises performed using MS-rehab software, benefits from several technological features such as the high-level configuration interface, the availability of different types of stimuli, the automatic mechanisms to increase the difficulty level of exercises, and the accessibility of the Web based interface (Gaspari et al., 2020); in the same way, exergames have emerged as virtual reality interactive systems more similar to most of the daily life activities, more enjoyable compared to conventional training, with advantages in adherence (Torre & Temprado, 2022).

Moreover, the involvement of a passive control group allows verifying that there is no test practice effect. Each training group may be considered as the active control group of the other. As an example, the improvement in the Cognitive Failures Questionnaire, which might have been influenced by the subjective expectancy effect of the training groups, is significant at follow-up only for the ATT-CCT group.

Even though all the three groups were comparable with regard to the gender ratio, it is evident that there was a significant over-representation of female participants in the study. Gender differences across a wide range of cognitive abilities have been reported in numerous studies (Herlitz & Yonker, 2002). In spite of the fact that the similar gender distribution in all of the three groups should guarantee that the observed positive changes in older adults' cognition are due to the impact of the training, not the gender bias, further studies with more balanced representation of men and women are needed. Moreover, with the tests selected it was possible to investigate only some aspects of attention, processing speed and memory. Therefore, it results essential to expand the assessment to examine in depth the various attentional components, to better investigate executive functions and other cognitive functions, such as memory, in particular working memory, considering

that they all decline in aging (Hedden & Gabrieli, 2004). Furthermore, it may be interesting to understand if there could be an improvement in terms of motor performance such as coordination (Schättin et al., 2016) and reaction times (Moret et al., 2021), due to the nature of the exergame which, differently from other cognitive training, also involves the motor system.

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Declaration of interest statement

No potential conflict of interest was reported by the authors.

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Table 1. Participants' demographic and baseline characteristics.

Group	ATT- CCT	EXERG-T	CG
N	27	28	29
Age (M ± SD)	70.89 ± 4.33	70.75 ± 3.89	69.03 ± 5.97
Education (M ± SD)	15.11 ± 5.3	14.57 ± 3.86	12.79 ± 3.75
Sex (F,M)	19, 8	22, 6	19, 10
CRI (M ± SD)	130.04 ± 21.02	131.61 ± 13.94	121.34 ± 13.19
BDI-II (M ± SD)	7.78 ± 6.24	5.46 ± 4.97	5.86 ± 3.58

Note. ATT-CCT: Attentional Computerized Cognitive Training; EXERG-T: Exergame Training; CG: Control Group; M: mean; SD: standard deviation; Education: number of academic years completed; F: female; M: male; CRI: Cognitive Reserve Index; BDI-II: Beck Depression Inventory- II.

Table 2. Cognitive performance means and standard deviations of Pre-test, Post-test, and Follow-up assessments of ATT-CCT, EXERG-T and CG groups.

	ATT-CCT (N=27)			EXERG-T (N=28)			CG (N=29)	
Assessment	Pre-test (mean ± SD)	Post-test (mean ± SD)	Follow-up (mean ± SD)	Pre-test (mean ± SD)	Post-test (mean ± SD)	Follow-up (mean ± SD)	Pre-test (mean ± SD)	Post-test (mean ± SD)
DS-F	6.52 ± 1.01	6.11 ± 1.21	6.30 ± 0.91	5.68 ± 1.12	5.79 ± 0.99	5.90 ± 1.07	6.24 ± 1.33	6.14 ± 1.25
DS-B	4.30 ± 0.87	4.37 ± 1.00	4.52 ± 0.94	4.48 ± 0.98	4.71 ± 1.30	4.75 ± 1.37	4.34 ± 1.42	4.52 ± 1.21
SDMT	45. 48 ± 10.15	51.93 ± 9.60	50.37 ± 10.34	46.79 ± 9.23	48.75 ± 10.96	48.55 ± 8.17	42.10 ± 8.17	43.86 ± 7.30
SRT-LTS	31.78 ± 14.33	39.73 ± 17.74	41.59 ± 17.12	37.32 ± 16.69	41.89 ± 15.53	46.75 ± 16.41	31.79 ± 11.85	30.62 ± 15.09
SRT-CLTR	20.81 ± 15.33	31.23 ± 17.41	32.56 ± 18.14	27.54 ± 14.35	31.93 ± 16.85	39.10 ± 19.30	21.55 ± 10.79	22.86 ± 12.51
SRT-D	5.96 ± 3.04	7.38 ± 2.82	8.07 ± 3.23	7.39 ± 2.72	8.07 ± 2.94	8.30 ± 3.03	5.03 ± 2.56	5.28 ± 2.99
CFQ	39.30 ± 12.03	32.22 ± 11.74	34.85 ± 13.88	31.82 ± 14.3	27.14 ± 12.86	29. 45 ± 12.21	32.45 ± 10.49	30.86 ± 10.32

Note. ATT-CCT: Attentional Computerized Cognitive Training; EXERG-T: Exergame Training; CG: Control Group; M: mean; SD: standard deviation; DS-F: Digit Span Forward; DS-B: Digit Span Backward; SDMT: Symbol Digit Modality Test; SRT-LTS: Selective Reminding Test-Long-Term Storage; SRT-CLTR: Selective Reminding Test-Consistent Long-Term Retrieval; SRT-D: Selective Reminding Test-Delayed; CFQ: Cognitive Failure Questionnaire.

Table 3. Mixed-effect analysis of variance (ANOVA) with main effects of Group (ATT-CC, EXERG-T, CG) and Testing session (Pre- and Post-test) and their interactions.

Dependent variables	Factors	df	F	p	Effect size η^2_p
	Group	2, 81	2.60	0.081	0.06
DS-F	Session	1, 81	1.23	0.270	0.01
	Group x Session	2, 81	1.49	0.232	0.04
	Group	2, 81	0.54	0.584	0.01
DS-B	Session	1, 81	1.28	0.261	0.02
	Group x Session	2, 81	0.12	0.888	<0.001
	Group	2, 81	3.50	0.035 *	0.08
SDMT	Session	1, 81	24.27	<0.001 ***	0.23
	Group x Session	2, 81	4.86	**0.010** *	0.11
	Group	2, 81.27	2.64	0.077	0.06
SRT-LTS	Session	1, 80.63	7.16	0.009 **	0.08
	Group x Session	2, 80.62	3.57	**0.033** *	0.08
	Group	2, 80.93	2.24	0.113	0.05
SRT-CLTR	Session	1, 80.26	16.04	<0.001 ***	0.17
	Group x Session	2, 80.25	3.74	**0.028** *	0.09
	Group	2, 81.22	6.73	0.002 **	0.14
SRT-D	Session	1, 80.53	10.74	0.002 **	0.12
	Group x Session	2, 80.53	1.82	0.169	0.04
	Group	2, 81	2.17	0.121	0.05
CFQ	Session	1, 81	26.28	<0.001 ***	0.24
	Group x Session	2, 81	3.36	**0.040** *	0.08

Note. DS-F: Digit Span Forward; DS-B: Digit Span Backward; SDMT: Symbol Digit Modality Test; SRT-LTS: Selective Reminding Test-Long-Term Storage; SRT-CLTR: Selective Reminding Test-Consistent Long-Term Retrieval; SRT-D: Selective Reminding Test-Delayed; CFQ: Cognitive Failure Questionnaire; * $p< 0.05$; **$p<0.01$; *** $p<0.001$.

Table 4. Post-hoc within-group comparisons between pre- and post-test measures.

	ATT-CCT				EXERG-T				
	t	df	p_{adj}	d [95% CI]	t	df	p_{adj}	d [95% CI]	t
SDMT	-4.6	26	**0.001 ****	- 0.90 [-1.35, -0.44]	-1.58	27	0.167	-0.30 [-0.69, 0.08]	-1.9
SRT-LTS	-3.67	25	**0.003 ****	-0.73 [-1.17, -0.29]	-1.8	27	0.125	-0.35 [-0.73, 0.05]	0.4
SRT-CLTR	-4.2	25	**0.001 ****	-0.84 [-1.29, -0.38]	-1.92	27	0.112	-0.37 [-0.76, 0.02]	-0.
CFQ	4.78	26	**0.001 ****	0.94 [0.47, 1.39]	2.59	27	**0.037 ***	0.50 [0.09, 0.89]	1.3

Note. *Post-hoc* t test showed significant improvements in all the tests for the ATT-CCT group. Only CFQ improved for both ATT-CCT and the EXERG-T groups. No improvements were found for the Control Group; p adj: p-value adjusted using false discovering rate; * $p < 0.05$; **$p<0.01$.

SDMT: Symbol Digit Modality Test; SRT-LTS: Selective Reminding Test-Long-Term Storage; SRT-CLTR: Selective Reminding Test-Consistent Long-Term Retrieval; CFQ: Cognitive Failure Questionnaire. ATT-CCT: Attentional Computerized Cognitive Training; EXERG-T: Exergame Training; CG: Control Group.

Table 5. Post-hoc within-group comparisons between pre- and follow up- test (3 months) measures.

ATT-CCT				
	t	df	p_{adj}	d [95% CI]
SDMT	3.45	26	**0.002** **	- 0.68 [-1.10, -0.25]
SRT-LTS	3.35	26	**0.003** **	-0.66 [-1.07, -0.23]
SRT-CLTR	4.01	26	**< 0.001** ***	-0.79 [-1.22, -0.34]
CFQ	-3.28	26	**0.003** **	0.64 [0.22, 1.06]
EXERG-T				
	t	df	p_{adj}	d [95% CI]
CFQ	-0.04	19	0.967	< 0.01 [-0.44, 0.46]

Note. *Post-hoc* t test showed a maintenance effect in all the tests for the ATT-CCT group. No improvements were found for the EXERG-T group. ** p< 0.01; **p<0.001.
SDMT: Symbol Digit Modality Test; SRT-LTS: Selective Reminding Test-Long-Term Storage; SRT-CLTR: Selective Reminding Test-Consistent Long-Term Retrieval; CFQ: Cognitive Failure Questionnaire. ATT-CCT: Attentional Computerized Cognitive Training; EXERG-T: Exergame Training.

Appendix A

Attentional Computerized Cognitive Training

Below are described examples for each of the category of exercises focused on different aspect of attentional domain:

- Prima uno e poi l'altro (First one, then the other)

The task requires participants to alternate their attention between two visual target stimuli. A series of pictures slides across the screen. The player is supposed to respond, with a click of the mouse, only to the ones representing the current target stimulus. Each trial is divided into several time intervals announced by an auditory signal. Every time the sound emerges, it serves as a cue for the player that they must switch from the first visual target stimulus to the second or vice versa (see Figure 2).

FIGURE 2 ABOUT HERE

- Su due fronti (On two fronts)

This exercise targets divided attention. It employs the dual-task paradigm. The task of the player is to select the target stimuli from the number of images that scroll across the screen and, at the same time, press the "sound" button every time when they are exposed to a certain auditory stimulus (see Figure 3).

FIGURE 3 ABOUT HERE

- Beccali al volo (A quick snach)

The task engages primarily selective and sustained attention. At the beginning of a trail, a series of target stimuli is being presented to the participants. They are asked to memorize them. Subsequently, the task is to choose – among different images appearing on the

screen – only those ones that initially have been presented as the target stimuli (see Figure 4).

FIGURE 4 ABOUT HERE

- Cogli gli oggetti (Catch them all)

The exercise targets selective visual attention. It is based on the visual search paradigm. A number of visual stimuli (images from a given semantic category) is being displayed on the screen simultaneously. The player's task is to select, as quickly as possible, all the target stimuli (shown at all times at the top of the screen) (see Figure 5).

FIGURE 5 ABOUT HERE

The order of the games played differed between sessions. For each category of exercises various classes of stimuli were available. Based on the class of the stimuli, the difficulty of the task varied. For all categories of exercises, participants started from the simplest, least perceptually complex objects, such as, fruits, vegetables, and animals which, with increasing task difficulty, were replaced by human faces or stimuli representing spatial concepts. The difficulty level was also influenced by parameters, such as, the number of stimuli, target-to-distractor ratio, colour brightness or the interstimulus interval. The player was moved to the next level of task difficulty having obtained at least 80% performance in two consecutive trails. Based on participants' capacities and information provided from data logs, experimenters had the possibility to change the difficulty level manually, in order to ensure optimal stimulation at all times. By means of this, it was ensured that the current training regimen complies with the principles of effective attentional training (Sohlberg & Mateer, 2001).

Having completed every single trial, participants were provided with general feedback generated by the system. In addition, the experimenters could have accessed more

detailed information about individuals' performance from the control panel. Nonetheless, after each of the eight training sessions, the researcher recorded the average score and final level reached on a dedicated protocol card.

Appendix B

Exergame training

The first meeting of the Exergame training consisted of a familiarization session with the gaming modality and equipment using a popular Xbox game - Fruit Ninja. The session was divided into three different game activities with increasing difficulty levels: in the first activity - Zen, the player had a minute and thirty seconds to slice as many fruits as possible using the arms; in the second one – Classic, the player had to achieve the best score before the end of play considering that missing a fruit or hitting a bomb leads to a life loss (only 3 lives); during the last activity – Arcade, the player had just 60 seconds to break the record slicing as many fruits as possible and avoiding bombs (a bomb means 10 seconds less) with no “life” lost. The same modality was repeated several times until the player achieved good ability and confidence in the game. The aim of this first game session was for the participants to learn how to interact with the Kinect using arm movements and to familiarize them with the virtual environment before starting to train cognitive functions and motor abilities.

The other training sessions were designed to stimulate both general cognition and sensory-motor abilities. From the second to the eighth session (7 sessions) the training was performed using “Dr. Kawashima's Body and Brain Exercises" (we used the Italian version), an exergame based on cognitive exercises requiring the involvement of both visuospatial and motion abilities. This exergame includes 20 different games divided by

categories. The training is adaptive to the participant's performance. It consists of three different levels of difficulty: basic, intermediate, advanced.

Ten activities out of 20 have been selected as the training activity. The main cognitive domains involved were: executive functions, processing speed, reaction times, visual working memory and visual search. Each game trains several cognitive functions, depending on the level of difficulty reached in each specific game.

The system, apart from providing its users with real-time visual feedback, gave them the possibility to track their daily progress by displaying the result in terms of percentage of accuracy, completing time of the task, and a general performance score. The results were recorded by the experimenter on a dedicated protocol card. To increase the difficulty level, the player had to obtain at least a C score. This rule has been applied to the evolution from basic to intermediate and from intermediate to advanced level of difficulty.

The Exergame Training was composed of the following games:

- Palloncini numerati (Numerical balloons) *

Several balloons displayed on the screen, each one contains a number. The goal is to make them explode in ascending order. The increasing magnitude of the numbers and the integration of negative numbers makes the task more difficult. Visual search, selective attention.

- Palloncini colorati (Coloured balloons) *

Balloons of different colours are being presented on the screen together with a square, displayed in the centre. Inside of the square, there is a word representing a colour that differs both from the ink of the square and the word. The goal is to burst the balloon matching the meaning of the written word, ignoring the ink colour of the word and the box that contains it. This game is intended to reproduce a modified version of the Stroop effect. Selective attention, inhibition.

- Vigile Urbano (Traffic policeman)

Vehicles of three different colours (red, yellow, and blue) must cross one of the three different bridges formed by the player's arms. The aim is to direct the vehicle on the bridge of the same colour. The difficulty raises when the vehicles' speed increases. Additionally, at the last level the vehicles move in both directions. Executive functions, inhibition.

- Topi turbolenti (Turbulent mice)

Several types of mice emerge from the pipes in which they are hiding. One of them has thorns on its head. The game becomes more difficult with increasing number of pipes and accelerating speed. The goal is to hit the mice as fast as possible while avoiding the rodent with thorns. Selective attention, inhibition.

- Gira e scopri (Turn and discover) *

Some geometric figures are displayed on the screen for a few seconds and then covered; the increasing number of figures and changes in colour and orientation raise the difficulty of learning and memorizing. The goal of the game is to uncover pairs of identical figures. Visuo-spatial working memory.

- Copia i passi (Memory step)

A walking path is illustrated as a sequence of footprints to the right, to the left or both. The aim is to reproduce the sequence by stepping to the left, to the right or jumping up, respectively. The difficulty increases with the number of steps to be made. The highest level consists of reproducing a sequence of footprints in which the sides have been swapped (the right becomes left and vice versa). Spatial working memory.

- Pallone d'oro (Golden ball) *

An algebraic equation is displayed; the game becomes more difficult with the integration of more than one operation at a time. The goal is to kick a ball with the number that

represents the correct solution of the equation. The missing number could be the result (e.g.: 2 + 3= X; basic level) or a number within the equation itself (e.g.: 3 – X + 4 = 5; advanced level). Processing speed.

- Che ore sono? (What time is it?) *

An empty analogue clock is displayed on the screen together the time presented in a digital form. The player's task is to use his/her arms to set the clock's hands in a way that reproduces the time displayed digitally. The difficulty increases with the requirement of performing mental calculations on the indicated time before reproducing it. Executive functions, processing speed.

- Radar (Radar)*

The needles of a radar rotate and there is an acoustic signal associated with each movement. After a while, the needles disappear, but the sound continues. The player should continue moving his/her arms rhythmically in order to point out the location of the needles ones the acoustic signal ends. The difficulty increases with the pattern complexity and the speed at which the radar rotates. Processing speed, working memory.

- Coppia perfetta (Perfect couple) *

Several geometric figures are presented and they remain visible at all time. The task is to indicate the perfect couple. The difficulty increases with changes of colours and orientation of the figures which - at the last level – keep rotating. Visual search, processing speed.

The presence of an asterisk (*) indicates that the game was timed: the timer was provided through both visual and sound feedbacks. If the activity was not performed within the time indicated, the trial was considered an error.

The order of the activities was kept identical for all sessions of training. For each activity, the playing time varied slightly, approximately 45 minutes, depending on the speed and

accuracy of the participant's performance.

List of figures' captions

Figure 1. Cognitive performance outcome in pre- and post-test measurements.

Note. Significant overall improvements were shown in all the tests apart from DS-F and DS-B for the ATT-CCT group. Only CFQ improved for both ATT-CCT and the EXERG-T groups. No improvements were found for the Control Group. Graphs **a**) Near-transfer effect tests: DS-F: Digit Span Forward, DS-B: Digit Span Backward and SDMT: Symbol Digit Modality Test. Graphs **b**) Far-transfer effect tests: SRT-LTS: Selective Reminding Test-Long-Term Storage; SRT-CLTR: Selective Reminding Test-Consistent Long-Term Retrieval; SRT-D: Selective Reminding Test-Delayed; CFQ: Cognitive Failure Questionnaire. ATT-CCT: Attentional Computerized Cognitive Training; EXERG-T: Exergame Training; CG: Control Group.

Figure 2. Example of a single trial of "Prima uno e poi l'altro" exercise with chess figures as stimuli category.

Figure 3. Example of a single trial of "Su 2 fronti" exercise with fruits as stimuli category.

Figure 4. Example of a single trial of "Beccali al volo" exercise with animals as stimuli category.

Figure 5. Example of a single trial of "Cogli gli oggetti" exercise with chess figures as stimuli category.