EFFECTS OF A BALANCE EXERGAMING ON EMOTIONS AND COGNITIVE FUNCTIONS. EXPERIMENTAL ANALYSIS AND LEARNING IMPLICATIONS.

EFFETTI DI UN ESERCIZIO DI EQUILIBRIO SULLE EMOZIONI E SULLE FUNZIONI COGNITIVE. ANALISI SPERIMENTALE E IMPLICAZIONI DI APPRENDIMENTO.

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Abstract

The several benefits associated with the use of exergames in relation to various domains of a physical and cognitive nature are the basis for the application of these tools in many areas related to the promotion of health and well-being. Many studies have highlighted how these cognitive domains, together with an adequate emotional regulation, turn out to be fundamental elements at the basis of learning processes. Our study dealt with analyzing the effects of balance training using exergames on selective attention, executive functions and on some important components of affectivity. The results obtained were compared with those obtained through an aerobic training session. The research was conducted on a sample made up of 23 able-bodied university students (mean age 28 ± 6). The results showed a significantly higher level of dominance in post-test exergames than in aerobic training (0<0,5). These results indicate the potential of exergames in implementing mood and promoting positive emotional states. Further research is needed for a deeper analysis of cognitive function and a check about the applicability of exergames programs in ad hoc structured didactic paths, with the aim of inserting a cognitive / motor training in programs of school or university learning.

I numerosi benefici associati all'utilizzo degli exergames in relazione a vari domini di natura fisica e cognitiva, sono alla base dell'applicazione di questi strumenti in molteplici ambiti correlati alla promozione della salute e del benessere. Diversi studi in letteratura hanno evidenziato come tali domini cognitivi, insieme ad una adeguata regolazione emotiva, risultino essere degli elementi fondamentali alla base dei processi di apprendimento. Il nostro studio si è occupato di analizzare gli effetti di un training dell'equilibrio mediante exergames sull'attenzione selettiva, le funzioni esecutive e su alcune importanti componenti dell'affettività. I risultati ottenuti sono stati confrontati con quelli ricavati attraverso una sessione di allenamento aerobico. La ricerca è stata condotta su un campione composto da 23 studentesse universitarie normodotate (età media 28± 6). I risultati hanno mostrato un livello di percezione del controllo significativamente più alto nel post prova exergames rispetto al training aerobico (<0,05). Tali risultati indicano le potenzialità degli exergames nell'implementazione dell'umore e nella promozione di stati emotivi positivi. Sono necessarie ulteriori ricerche che utilizzino batterie di test più complete per l'analisi della funzionalità cognitiva e che verifichino l'applicabilità di programmi di exergames in percorsi didattici strutturati ad hoc, nell'ottica di inserire un training di tipo cognitivo/motorio in programmi di apprendimento di stampo scolastico o universitario.

Keywords

exergames, aerobic exercise, learning, dominance, balance training.
exergames, esercizio aerobico, apprendimento, percezione del controllo, training dell'equilibrio.

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Introduction

The word "exergames" is used to define the wide range of video games that, through a virtual medium, allow the user to engage in various types of physical exercise (Anders et al., 2018). In fact, "exergaming" presents itself lexically as a crasis between the terms "exercise" and "gaming" and refers to the idea behind the development of gaming platforms that combine, in a perfect union, the most advanced digital interfaces and bodily movement (Stanmore et al., 2017). These features allow exergames to overcome the traditional stereotypical view, associated with video games and the digital world as a whole, which links these tools to a sedentary and unhealthy activity (Lamboglia et al., 2013). In fact, in addition to a more dynamic mode of play, exergames are increasingly used in clinical settings, in particular in medical and psychological contexts, for the treatment of various diseases such as depression (Li et al., 2016), anxiety disorders (Viana et al., 2020) and motor and cognitive impairments related to neurodegenerative diseases such as Parkinson's Disease (Schaeffer et al., 2019) and Multiple Sclerosis (Schättin et al., 2021). The article shows the results of an experimental study investigating the potential benefits of exergaming in some cognitive functions, such as selective attention, executive functions and on some important components of affectivity. The aim is to verify the opportunity to consider exergames as an integration of established practices in different areas of education.

1 Exergames and learning

It is now known the importance of motor activity and, in particular, the teaching of techniques that allow the learning of the skills necessary for a harmonious development of one's body and a full awareness (Staiano & Calvert, 2011). Several studies showed as serious games (a form of videogames) used in school settings, during physical education hours, had a positive influence in the implementation of visuo-spatial skills, selective attention and problem solving skills (Dimitrova et al., 2017), as well as in the improvement of psychophysical well-being (Andrade et al., 2020; Han et al., 2020). The positive effects associated with the use of exergames, constitute the motivational drive to perform physical activity even in adulthood and thus contribute to the maintenance of a healthier lifestyle (Soltani et al., 2021). The use of educational video games with children and adolescents (main target) highlights how the positive intrinsic motivation and emotions for a playful activity promotes learning, directing the motivational drive towards a knowledge activity (Marasso, 2015). In particular, some studies related to the application of exergames in coordination and balance training in children have reported promising outcomes (Sgrò et al., 2017; Mombarg et al., 2013).

Two constructs are significantly positively affected by the use of exergames: self-esteem and self-efficacy. These domains are crucial in fostering good learning processes, as they are strongly related to the implementation of a sense of awareness of one's own competences (Krause & Benavidez, 2014; Andrade et al., 2020), according to the emotional evaluation made by the subject in response to the stimuli he or she faces (Maaswinkel et al., 2020; Stevens et al., 2016). The latter concept is systematized in the domain of control perception, which is a composite construct given by the outcome of the effects of emotional and cognitive variables processed by the subject based on the context. Good levels of control perception allow the subject to feel capable in a given situation and reflexively improve his/her mood (Maaswinkel et al., 2020). In fact, according to Dewey's construct of optimal challenge, a task should be challenging for the subject but should not require an effort (both physical and cognitive) that exceeds his or her abilities (Marasso, 2015). Therefore, good quality exergames operate by maintaining this balance, through the ability to play in a controlled virtual environment and set trials based on skill level (Andrade et al., 2020).

Ultimately, the common belief that all video games are associated with sedentary activities and therefore promote obesity (Lamboglia et al., 2013), is to be considered incorrect. In fact, based on the evidence, exergames can become excellent allies in enhancing the role of movement in traditional teaching pathways, through the high transferability of the skills learned in real contexts (Marasso, 2015; Kiili et al., 2014; Gordon & Ramani, 2021).

However, several critical issues arise among the research carried out in this area, mainly attributable to the low ecological validity of many of them, due to the excessive heterogeneity of the studies that do not present, therefore, uniformity of results (Sgrò et al., 2017).

2 The study

The field of investigation of our research project concerns the evaluation of the effectiveness of a training through exergames on some domains of motor and cognitive nature, through the comparison with a traditional exercise session, in young adults (Dimitrova et al., 2017; McDonough et al., 2018; Stanmore et al., 2017). In this case, as concerns the exergames, we used balance training based on some Nintendo Wii mini-games using the Balance Board, while for aerobic training the use of an elliptical has been preferred. The purpose of this study concerns the analysis of the differential impact of the two types of training on executive function (inhibition capacity), attention (selective attention) and subjective emotional state, in order to evaluate the potential of exergames in the implementation of cognitive and affective functions, that are central to learning processes.

2.1 Materials and methods

2.1.1 Participants

The research was carried out on a sample of 23 able-bodied female university students, without pathologies, aged between 21 and 36 years (average 28± 6) with different socio-economic backgrounds and athletic training. Personal data were collected in order to obtain information on: educational qualifications, occupation, mother tongue, presence of learning disabilities, height and weight. In this sense, the sample was composed of 18 high school graduates and 5 university graduates, 22 are native Italian speakers. As concerns the type of employment, parallel to university studies, only 13 of them have an occupation and 12 carry out a physically demanding job. Moreover, given the peculiarity of physical exercise through exergames, which requires the creation of a personalized profile to set up the tests, the weight and height of the participants were noted. In this sense, we calculated an average weight of 56 kg ±8 and an average height of 162 cm±8.

2.1.2 Experimental conditions

The study has been structured through the use of a multiple-treatment non-counterbalanced research design.

The experimentation took place in a controlled environment, so as to minimize disturbing factors. Specifically, the administration of the reagents in digital format was carried out the H.E.R.A.C.L.E. Laboratory of the Niccolò Cusano University of Rome. On the other hand, to carry out the physical training phases (exergames and elliptical) we made use of the special equipment available in the university gym. All phases of the experimental procedure have been supervised by qualified professionals and the research has been conducted in compliance with current health regulations aimed at reducing the infection from Covid-19.

The experimental phases followed a precise protocol repeated on two consecutive days in the following manner:

1. Digital administration of the Manikin Self-Assessment for pre-test emotional state assessment;

2a. Balance test with mini-games on the Wii Fit Plus platform, with the aid of the Balance Board platform, lasting 20 min (first day);

2b. Physical activity by means of the elliptical machine lasting 20 min (second day);

3. Digital administration of the Manikin Self-Assessment for the assessment of emotional state post-test;
4. Administration of the Stroop test in computerized version;
5. Digital administration of the Intuitive Mathematics test

2.1.3 Questionnaires

The tests used were digitally administered, using the Google Modules platform (Health Status Questionnaire, Self-Assessment Manikin, and Intuitive Mathematics test) and Psytoolkit software (Stroop test), (Stoet, 2010).

Health Status Questionnaire: This instrument is a translated and adapted version of the PAR-Q (Physical Activity Readiness Questionnaire, 2002) from the Canadian Society for Exercise Physiology. Translation and adaptation of the questionnaire were performed by the SSD Sports Medicine of ASL TO4. During the recruitment phase, subjects completed this instrument in order to assess both the presence of medical problems (in particular cardio-respiratory and musculoskeletal diseases) and sports habits.

Self-Assessment Manikin: (Bradley & Lang, 1994): this self-report test allows an assessment of affective state through the analysis of three specific domains: level of perceived pleasure, level of arousal (or arousal), and perception of control (Stevens et al., 2016).

Stroop test (computer version): This test consists of an ink color recognition test in which a series of stimulus words, related to color names, are written and, in the inhibition of the concomitant automatic reading response. The purpose of the test is to create cognitive and semantic interference aimed at analyzing a number of domains, namely: executive functions, specifically cognitive inhibition and selective attention (Normah & Edbert, 2019).

Intuitive Mathematics Test: It is a shortened version of the Intuitive Mathematics Test developed by Dr. Stefania Morsanuto (Morsanuto, 2021) for the assessment of logical-mathematical skills and is composed of a series of logic, algebra, and geometry tests carefully selected to measure logical-mathematical skills indicative of the level of development of computational thinking. Specifically, the test consists of 31 items divided into three sub-scales: Geometric Figures (11 questions), Card Domain (9 questions), and Logic-Visual Mathematics (11 questions).

3. Results

The analysis of the differential impact of the two types of physical exercise on cognitive functions was evaluated through an analysis of multivariate variance (MANOVA) which showed no statistically significant differences between the two trainings.

On the other hand, regarding the evaluation of the training on subjective emotional state, we applied a paired samples t-test in order to compare the results obtained in the Manikin Self-Assessment in the post physical training of each type of training and a 95% confidence interval was chosen. The results show significantly higher values in the test of balance between post training of each type of exercise only in the domain of self-control $t(22) = -2.515$ $p < 0.05$ (Figure 1).

Post-Test Balance		Post-Test Elliptical	t	df	p
Perceived Pleasure Level	-	Perceived Pleasure Level	1.127	22	0.272
Arousal Level	-	Arousal Level	0.533	22	0.599
Perception of control	-	Perception of control	-2.515	22	0.020

Figure 1 - Paired Samples T-Test: post-test balance – post-test elliptical

In addition, analyzing the data obtained at the pre- and post-balance exercise, significant differences result in both the domain of self-control with $t(22) = -2.426$ $p < 0.05$ and the level of arousal $t(22) = 2.651$ $p < 0.05$ in the post-exercise balance test (Figure 2).

Pre-Test Balance		Post-Test Balance	t	df	p
Perceived Pleasure Level	-	Perceived Pleasure Level	1.679	22	0.107
Arousal Level	-	Arousal Level	2.651	22	0.015
Perception of control	-	Perception of control	-2.426	22	0.024

Figure 2 - Paired Samples T-Test: Pre-test balance – Post Test Balance

The data obtained at pre and post-elliptical training, no significant differences were found in three domains (Figure 3).

Pre-Test Elliptical		Post-Test Elliptical	t	df	p
Perceived Pleasure Level	-	Perceived Pleasure Level	-1.219	22	0.236
Arousal Level	-	Arousal Level	-0.095	22	0.926
Perception of control	-	Perception of control	-0.167	22	0.869

Figure 3 - Paired Samples T-Test: Pre-test Elliptical – Post Test Elliptical

An additional t-test was performed to compare the emotional state experienced prior to the two tests, with a view to establishing a common baseline in order to more clearly frame the effects of the two types of exercise on emotional state as measured by the Manikin. The results of the latter analysis show that the level of pleasure and arousal are significantly higher before the elliptical test, $t(22)= -2.040$ $p<0.05$ and $t(22)= -2.256$ $p<0.05$, respectively (Figures 4).

Pre-Test Balance		Pre-Test Elliptical	t	df	**p**
Perceived Pleasure Level	-	Perceived Pleasure Level	-2.040	22	0.054
Arousal Level	-	Arousal Level	-2.256	22	0.034
Perception of control	-	Perception of control	-0.277	22	0.784

Figure 4 - Paired Samples T-Test: Pre-test Balance – Pre-test Elliptical

This result could be indicative of the fact that the subjects, having participated in the day before the first experimental phase, are more predisposed to the performance of aerobic exercise, because they have already had the opportunity to engage in the tests that they are going to perform after the physical test. However, although starting from a more positive emotional state, the domains of control and arousal are significantly higher in the post-test of balance than the pre-test, unlike what happens in the post-test elliptical (Figure 3). This result could therefore be a good indicator of the positive effects of exergames training on the emotional state, having available cleaner data because not influenced by the learning effect. In addition, it is however necessary to specify that significantly higher values in the pre-test elliptical may be attributed to the lack of significant effects in the post-test of this physical exercise. In fact, the higher values in the pleasure level and the arousal level may have attenuated the possible positive effect of aerobic exercise on emotional state, explaining the absence of statistically significant differences between the two times of the experimental phase.

4. Limitations and methodological considerations

The study has some critical issues to be attributed primarily to the low sample size that does not allow to generalize the results to the reference population. In addition, there are some methodological limitations, starting with the research design that did not provide for the balance of the training presented, proposing as a fixed protocol the implementation of the two training sessions on two consecutive days. The administration of the tests at close time intervals has, consequently, caused a significant learning effect that prevents the adequate quantification of the impact of each training on the domains under analysis. In fact, the data from the aerobic post-test are partially skewed by the participants' greater ability to complete the cognitive tests compared to the exergames post-test. This is due to the short time interval between the two sessions, which makes the cognitive tasks easier to solve in the second part of the experiment, since the participants have already had a chance to engage in the tasks the day before. These choices have been affected by the restrictions imposed by the Covid-19 pandemic, which severely limited the research activity and forced a study planning in very narrow time windows. Consequently, the sample was also affected by logistical factors that restricted the recruitment pool to only female students who participated in the study. Another limitation that needs to be filled concerns the use of the single-item scales of the Manikin Self-Assessment for the assessment of subjective emotional state. This led to a not in-depth analysis of pre-post test emotional changes.

5. Conclusions and future perspectives

On the basis of the results, we can set up a series of research trajectories regarding the in-depth study of the construct of the perception of control and its relationship with learning processes. In this sense, it would be useful to structure research projects that aim to analyze, through accurate psychometric batteries, the wide emotional spectrum that influences the cognitive processing of environmental stimuli. It will therefore be useful to evaluate, in this context, the correlation between the perception of control and executive functions. The latter are in fact responsible for monitoring mental processes that allow to filter interfering information and direct attention to relevant inputs (Huang, 2020). Therefore, since the attribution of priority to a stimulus rather than another depends significantly on the emotional value assigned to it, a more or less optimal perception of control will be the result of the synergistic work of brain circuits, responsible for processing information from memory (related to the meaning to be attributed to a stimulus) and those from the environment. These neural circuits, belong to the prefrontal cortex, deputed to the implementation of executive monitoring mechanisms that allow to integrate the different sources of information and to produce an appropriate response (Xiong et al., 2019; Anders et al., 2018). These mental processes are closely related to learning mechanisms and can be implemented with tools such as exergames that offer the possibility of using a virtual environment that can be modified as needed, while allowing for more accurate quantification of the use of different domains of a motor and cognitive nature. In this sense, an interesting prospect of future research concerns the study of the application of exergames programs within school curricula, through the creation of video games built according to the needs. For example, active games could be set up to train specific motor domains such as coordination and balance to implement the teaching of physical education at school. In addition, the evidence in the literature shows promising results with regard to the use of exergames in improving school performance, through training that implements the basic cognitive functionality, going to act on specific domains such as selective attention and executive functions, in order to elicit an improvement of neural circuits at the base of learning processes. Moreover, the possibility of structuring ad hoc training through exergames, opens the way to prospects of great interest in education. In fact, future investigations in this area could study the applicability of learning programs built with the aim of promoting the acquisition of knowledge in the school curricula, in addition to traditional teaching methodologies. In this sense, the creation of learning paths in which movement plays a major role, highlights the relevance of studies that analyze the direct involvement of neurobiological mechanisms, deputies to the integration of certain types of movements on the processes of knowledge acquisition. Therefore, the creation of exergaming programs structured according to the learning object, should take into account the evaluation of the implementation of movements directly related to the implementation of specific neural circuits, in order to structure didactic protocols that allow to rethink the school according to an embodied perspective.

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