Confronto tra *exergames* ed esercizio aerobico. Valutazione degli effetti sulle emozioni e le funzioni esecutive

Comparing exergames and aerobic exercise. Evaluation of the effects on emotions and executive functions

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ABSTRACT
The study presented aims to investigate the impact of a balance training conducted by exergames on some domains of a cognitive and affective nature, in a sample of university students (average age 28 ± 6). In this sense, executive functions, selective attention and subjective emotional state were evaluated. These constructs were chosen because of their centrality in fostering learning processes. The effects of *exergaming* were compared with those obtained through aerobic training of the same duration (20 min). The results showed a similar impact of the two types of training on the cognitive domains under analysis, while a statistically difference was observed with respect to higher levels of dominance (<0.05) in the post-test exergames measured. through the SAM (Self-Assessment Manikin). The research carried out has allowed to highlight the opportunity to use these tools in the implementation of positive affectivity in young adults.
On the basis of the results obtained, it is therefore possible to set future research directions relating to the study of the effects of exergames on constructs related to the dominance, such as self-esteem and self-efficacy and the relationship of these with high-level cognitive functions, whose integration is necessary for the structuring of learning programs in different training contexts.

Lo studio presentato ha la finalità di indagare l'impatto di un training dell'equilibrio condotto mediante *exergames* su alcuni domini di natura cognitiva e affettiva in un campione di studentesse universitarie (età media 28± 6). In tal senso, sono state valutate le funzioni esecutive, l'attenzione selettiva e lo stato emotivo soggettivo. Tali costrutti sono stati scelti per la loro centralità nel favorire i processi di apprendimento. Gli effetti del training mediante *exergaming* sono stati confrontati con quelli ottenuti attraverso un allena-

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mento aerobico di pari durata (20 min). I risultati ottenuti hanno mostrato un impatto similare delle due tipologie di allenamento sui domini cognitivi in analisi, mentre è stata osservata una differenza statisticamente significativa rispetto a più alti livelli di percezione del controllo (< 0,05) nel post-prova *exergames* misurato attraverso il SAM (*Self Assessment Manikin*). La ricerca condotta ha permesso di fornire un'evidenza sull'opportunità di utilizzare questi strumenti nell'implementazione dell'affettività positiva nei giovani adulti.

Sulla base dei risultati ottenuti è, quindi, possibile impostare direzioni di indagine future relative allo studio degli effetti degli *exergames* su costrutti correlati alla percezione di controllo, come l'autostima e l'autoefficacia e la relazione di questi con funzioni cognitive di alto livello, la cui integrazione è necessaria per la strutturazione di programmi di apprendimento in diversi contesti formativi.

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

Introduction

Exergames or active games are a wide range of video games that require the user's body movements in order to function (Brox et al., 2011). Such devices, can be considered dual tasks, since they require the simultaneous and complementary involvement of the subject's cognitive and motor resources (Anders et al., 2018). The digital realities developed in this sense, in fact, combine in a perfect union the most advanced interfaces and body movement, generating a highly immersive gaming experience, in which it is the whole body that gives commands. Although many commercially available exergames have been developed for recreational purposes, in recent years there has been a proliferation of applications of these video games in various areas related to health promotion (Monteiro-Junior et al. 2016). In addition, the characteristics of exergames make this technology accessible to all age groups (Stanmore et al., 2017), in particular, children and adolescents represent the main targets affected by the benefits of these tools, because they are more inclined and literate in their use (Andrade et al., 2020).

1. Exergames in didactic.

The wide use of video games by children and adolescents has encouraged researchers to develop applications of these games in school settings and, in particular, in physical education teaching (Staiano & Calvert, 2011). The latter is crucial to learn the technical skills necessary for obtaining good mastery of one's body that promotes optimal motor development (Sgrò et al., 2017). Some video games in the form of serious games are used in various contexts for the implementation of visuo-spatial skills, selective attention, and problem solving skills (Dimitrova et al., 2017). Interesting results have also been observed regarding the application of exergames in improving mood and emotional well-being in general (Andrade et al., 2020; Zheng et al., 2020). Despite this evidence, there is still much resistance from institutions as concerns the inclusion of these tools in educational curricula. There are many reasons for this, but they refer in particular to the widespread stereotype that sees all video games as purely sedentary activities and, as such, directly related to the development of obesity (Lamboglia et al., 2013). On the contrary, numerous studies show the great potential of exergames in promoting a more active lifestyle (Marasso, 2015). In this context, the video games find application in the training of specific motor domains, such as coordination and balance in children (Mombarg, Jelsma & Hartman, 2013; Sgrò et al., 2017). In addition, the benefits of exergames on social skills must be taken into account, due to the possibility of being able to play multiplayer games in both cooperative and competitive formats and ensuring both physical and virtual interaction (Staiano and Calvert, 2011).

Therefore, it is possible to say that video game has the potential to be used profitably within school programs, in addition to traditional teaching methods. In particular, from the point of view of motor learning, exergames allow the creation of cognitive maps of body movements used during game activities that, in addition to improving general motor skills, also facilitate the development of persistent neural patterns, necessary in highly stimulating contexts where complex and specific motor skills are required (Sgrò et al., 2017). The benefits of exergames in this domain are significantly mediated by the content delivery, i.e. through a virtual environment in which the player is involved in different tasks that require player's motor and cognitive resources (Anders et al., 2018). In this context, the construct of spatial presence plays a major role, which significantly influences executive functions (inhibition capacity and cognitive flexibility, in particular) and selective attention, through the stimulation of the dorsolateral prefrontal cortex, directly involved in the imaginative processes enacted by the player in order to operate adequately in the virtual environment (Huang, 2020). Because of their characteristics, exergames allow the development of an intrinsic motivation to carry out the game activity and, in the case of video games of didactic-educational type, this motivational drive will be directed towards the contents that the activity proposes and, consequently, towards learning itself (Marasso, 2015). In fact, in health promotion area, with a fairly dispersed and controversial landscape, studies on exergames have shown excellent results in terms of increasing motivation to perform physical activity (Soltani et al., 2021).

These findings are particularly important because they point the player toward maintaining a good level of fitness over time and, consequently, in the direction of a more active and healthy lifestyle (Sgrò et al., 2017). A key component of motivation is the feeling of mastery of one's skills (Marasso, 2015), which reflects the influence of emotional and cognitive components mediated by one's experience (Maaswinkel et al., 2020). This domain is closely related to self-esteem and self-efficacy, two important constructs on which exergames have shown excellent results (Krause & Benavidez, 2014). Concerning this concept, it is necessary to emphasize its relation with Dewey's construct of optimal challenge, according to which, a task should be a challenge for the subject but should not require an effort (both physical and cognitive) that is excessively beyond his/her abilities (Marasso, 2015). The sense of mastery of one's skills is closely related to the perception of control, i.e., the degree to which the subject's emotional experience makes him or her feel more or less in control of the situation (Stevens et al., 2016). This construct strongly influences mood as demonstrated by several scientific studies where some balance training through exergames improved it (Andrade et al., 2020; Han et al.,2020).

In this sense, one of the features that allow exergames to pose themselves as useful learning tools is the possibility of offering the player a controlled virtual environment in which to freely express his/her skills in relation to predetermined tasks, through challenges customized according to his/her skill level (Marasso, 2015; Xiong et al., 2019). Regarding the teaching of physical education, exergames can be included within sections of the curriculum in order to exercise specific motor domains (such as coordination and balance) (Sgrò et al., 2017). Moreover, workouts conducted through exergames have the advantage of making the student's assessment more complete, as it is enriched by the parameters measured by the software as needed (Kiili et al., 2014). In this sense, useful examples of applications of this type could refer to the analysis of reaction times in selective attention training, or the measurement of movement accuracy in athletic improvement training. However, the encouraging results obtained in the cognitive, motor and social domains (Lamboglia et al., 2013), mainly refer to short-term benefits (Staiano & Calvert, 2011). Based on the evidence, it is clear that exergames can be excellent support tools to complement traditional teaching due to the high transferability of skills learned through video games in everyday life contexts. Studies dealing with the analysis of the impact of such devices in schools have shown very interesting results, both in relation with the effects of commercially available games, such as those developed for the Nintendo Wii and Microsoft Kinect platforms, and with ad hoc created tools (Marasso et al., 2015; Kiili et al., 2014). However, further studies related to the investigation of the long-term effects of virtual environment mediated teaching are needed. The scientific landscape does not present unanimous evidence on the effects of various trainings because of the excessive heterogeneity of studies and the low ecological validity of many of them.

2. The project.

In this context, our study aims to evaluate the impact of balance training conducted by means of exergames on selective attention and executive functions, as well as on subjective emotional state. The effects of this training were compared with those obtained through aerobic training (elliptical) of the same duration (20 min). As for the exergame, some Nintendo Wii mini-games were used with the help of the Balance Board. Specifically, the level of difficulty of the tests was structured on some parameters related to the functionality of balance skills, analyzed through some initial assessment tasks. The architecture of the project is based on the hypothesis that training through exergames would have produced better results on the domains under study. The formulation of this hypothesis is based on several evidences regarding the achievement of similar or superior results by exergames in the implementation of different cognitive domains (Stanmore et al., 2017; Anders et al., 2018; Dimitrova et al., 2017) and in the improvement of mood (Andrade et al., 2020; Han et al., 2020). These results could be due to the integration between motor and cognitive stimulation offered by exergames. International literature reports many studies dealing with the analysis of the differential impact of these two trainings on cognitive and motor functions in different age groups (Dimitrova et al., 2017; Monteiro-Junior et al., 2016; Stanmore et al., 2017). Particularly significant results come from research conducted on samples of young adults experiencing different types of exergames and then compared with aerobic training sessions (McDonough et al., 2018; Su & Zeng, 2020). Through our reaserch, we aim to investigate the impact, in the short term, on the mental domains under analysis, and we expect results at least of comparable magnitude to that reported in the literature for traditional aerobic exercise (Alkadhi, 2018; Stanmore et al., 2017). In conclusion, our research aims to highlight and quantify the benefits obtained from exergames on psychophysical well-being, so as to be able to offer a useful contribution to the scientific community regarding the use of these tools in protocols of motor and cognitive enhancement to be applied in the educational field.

2.1 Materials & Methods

2.1.1 Participants

The research was carried out on a sample composed of 23 normotensive female college students between 21 and 36 years of age (mean 28± 6) with various socio-economic backgrounds and different athletic training. Inclusion criteria used for sample composition are:

(a) Absence of cardiovascular disease;
b) Absence of balance disorders;
c) Absence of musculoskeletal disorders;
d) Absence of disorders not belonging to the categories previously reported but which manifest themselves in a particularly disabling way.

Personal data were also collected in order to obtain information on: title of study, occupation, mother tongue, presence of learning disabilities, height and weight. In this sense, the sample is composed of 18 high school graduates and 5 university graduates, 22 are native Italian speakers. With regard to the type of employment parallel to university studies, only 13 of them have an occupation and 12 have a job that requires physical activity. Moreover, given the peculiarity of physical exercise through exergames, which requires the structuring of a personalized profile to set up the tests, the weight and height of the participants were noted. The average weight was 56 kg±8 with an average height of 162 cm±8. Finally, no participant was diagnosed with an ASD.

2.1.2 Objectives and hypothesis.

In addition to the mentioned main research hypothesis, this study aims to investigate some sub-objectives:

1) The different impact of the two types of training on cognitive functions (selective attention, executive control, and logical-mathematical skills);
2) The influence of the two trainings on the emotional state of the participants in order to understand which of the two has a more significant influence.

2.1.3 The experimental procedure.

This study was structured using a multiple treatment non-counterbalanced research design.

Our research aims to compare two types of physical activity: traditional and video game mediated, in order to analyze any changes in emotional and some cognitive functions. Specifically, the experimental procedure is divided into two parts that are carried out in two consecutive days.

All phases of this procedure were carried out in a controlled environment, in order to minimize the disturbing factors. Specifically, the administration of the reagents in digital format took place in specially prepared rooms made available by the H.E.R.A.C.L.E. Laboratory of the Niccolò Cusano University of Rome. Instead, the performance of the physical training phases (exergames and elliptical) took place in the gym through the use of verified instruments. All phases of the experimental procedure were supervised by qualified professionals and the research was conducted in accordance with the current health regulations aimed at reducing Covid-19 contagion.

The testing phases were carried out on two consecutive days in the following manner:

Day 1:
1. Digital administration of the Manikin Self-Assessment for pre-test emotional state assessment;
2. Balance test through mini-games of the Wii Fit Plus platform, with the aid of the Balance Board platform, lasting 20 min;
3. Digital administration of the Manikin Self-Assessment for post-test emotional state assessment;
4. Administration of the Stroop test in computerized version;
5. Digital administration of the Intuitive Mathematics test.

Day 2:
1. Digital administration of the Manikin Self-Assessment for pre-test emotional state assessment;
2. Physical activity via elliptical of 20 min duration;
3. Digital administration of the Manikin Self-Assessment for post-test emotional state assessment;
4. Administration of the Stroop test in computerized version;
5. Administration of the Intuitive Mathematics test.

2.1.4 Measurements

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

Health 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 possible presence of medical problems (in particular cardio-respiratory and musculoskeletal diseases) and sports habits.

Manikin Self-Assessment (Bradley & Lang, 1994): this self-report reagent allows for 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 are written, related to color names and in 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). The test in question was programmed using Psytoolkit software (Stoet, 2010) and consists of the presentation of 40 items depicting color names written in: green, blue, yellow, and red. The test consists of clicking the initial letter of the color of the word on the keyboard. The items are divided into congruent, incongruent and neutral; the first ones are the words indicating one of the mentioned colors and colored with the same type of ink (e.g. RED), the second ones are the names that show incongruence between the name of the color and the ink with which the word is presented (e.g. BLUE) and, finally, the neutral stimuli are names of colors written in white to which participants must respond by clicking on the space bar when they appear. The task consists of 40 items preceded by a rehearsal exercise that consists of a 15-item approach task to the mechanisms of the test. In both components of the test, the stimulus-words appear with an interval of 500 ms between each one and remain on the monitor for 2000 ms before the answer is invalidated because it is out of the maximum available time.

Intuitive Mathematics Test: This reagent 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 analyze 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).

2.1.5 Health Questionnaire Data Anaysis

The participants do not have any health problems that would lead to exclusion from the study.

With regard to the items concerning physical activity, of the 23 participants, only 5 do not practise a sport, while the remaining 23 are involved in various sporting activities distributed in the sample as follows: volleyball (1), gym (3), pilates (2), mountaineering (1), sports walking (3), zumba (1), personal (1), dance (2), basketball (1), mixed functional training (1), running (1), artistic gymnastics (1). The frequency of sport practice follows the pattern: 2 times a week (11), 3 times a week (2), 4 times a week (4), 5 times a week (1). The training sessions last: 30 min (4), 40 min (4), 45 min (1), 50 min (1), 60 min (4), 90 min (2), 120 min (2). In addition, the average time the subject walks at a brisk pace was also assessed in the questionnaire: 10 min (5), 10-30 min (7), 30-60 min (10), no walking (1).

3. Results

Data analysis was carried out using the statistical software Jasp 0.14.1.0 with the aid of Microsoft Excel for database creation and qualitative analysis.

3.1 Stroop and Intuitive Mathematics Tests

The differential impact of the two types of exercise on cognitive functions was assessed by means of a multivariate analysis of variance (MANOVA), which showed that there were no statistically significant differences between the two trainings (Figure 1).

Cases	df	Approx. F	$Trace_{Pillai}$	Num df	Den df	p
(Intercept)	1	6.028.960	1.000	18	27.000	< .001
Training type	1	1.315	0.467	18	27.000	0.254
Residuals	44					

Figure 1 - MANOVA: Balance test – Elliptical

Analysing the ANOVA (Figure 2) for each domain comparison individually, it is evident that the mean response time to the neutral stimuli of the Stroop test is significantly higher after the elliptical training than after the balance test, taking into account a 95% confidence interval, thus $F(1, 44)= 6.283$ $p<0.05$.

Cases	Sum of Squares	df	Mean Square	F	p
Training type	118.120.891	1	118.120.891	6.283	0.016
Residuals	827.243.913	44	18.800.998		

Figure 2 - ANOVA: Average reaction times (ms) neutral stimuli

This result can be read in the light of the learning effect caused by administering the reagents on two consecutive days. In fact, we can hypothesize that the time interval between the two administrations is insufficient to make the two research phases independent of each other, to the extent that the results obtained in the cognitive tests are due to the effects of the type of physical training.

On the basis of these results, it is not possible to indicate the balance test by exergames as the most effective type of exercise on cognitive improvement in comparison with the elliptical. Although there is not enough statistical significance to establish a primacy for the effectiveness of one type of training over the other, it is nevertheless possible to show some differences between the two types of exercise in the scores obtained in various cognitive domains. In this sense, in order to present a more complete analysis, a further qualitative analysis was carried out that showed that the performance on the subscale Geometric figures of the Intuitive Mathematics test and the accuracy in responding to incongruent stimuli of the Stroop test is better in the elliptical post-test.

On the contrary, the averages of reaction times in response to congruent, neutral and incongruent stimuli are higher in the exergames post training than in the elliptical, as well as the facilitation effect of the Stroop test and the standard deviations in reaction times to incongruent and congruent stimuli in the same test.

An interesting finding is provided by the comparison of the interference effect, facilitation and the Stroop effect proper between the two data sets. These three indices represent the most reliable indicators of executive and attentional functionality obtainable through the use of the Stroop test (Parris, 2014) and, in the analysis using MANOVA, they do not differ in a statistically significant way between the two groups. However, we can still show a higher interference effect and Stroop effect after aerobic exercise and a higher facilitation effect after the balance test. This result appears discordant with the other analyses that showed almost similar results between the two trainings in the other cognitive domains, because in this case the values show a better overall performance on the Stroop test and, consequently, a greater effect of the exergames exercise on executive and attentional functionality, although this is not statistically significant. Finally, the analysis of standard deviations around the averages of reaction times to congruent, incongruent and neutral stimuli, shows that there is greater variability in the data in the group of the balance test than the elliptical in the first two types of stimuli with the presence of significant outliers. On the contrary, the standard deviations of reaction times to neutral stimuli are greater in the elliptical than in the equilibrium test.

The other values show an almost equal impact of the two exercise types on cognitive performance.

3.2 Self-Assessment Manikin

In order to compare the results obtained by the participants in the Manikin Self-Assessment in the post physical training of each training type, a paired samples t-test was applied and a 95% confidence interval was chosen.

The results obtained, show significantly higher values in the balance test between the post training of each exercise type 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

Furthermore, when analysing the data obtained at pre and post-balance training, significant differences were found both in the domain of self-control with t(22)= -2.426 p<0.05 and in the level of arousal t(22)= 2.651 p<0.05 in the post 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

In addition, a further t-test was carried out to compare the emotional state experienced prior to the two tests, with a view to establishing a common baseline that would allow the effects of the two types of exercise on the emotional state measured by the Manikin to be framed more clearly. The results of the latter analysis show that the level of pleasure and arousal are significantly higher before the elliptical test, respectively t(22)= -2.040 p<0.05 and t(22)= -2.256 p<0.05 (Figure 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 try 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. We can therefore hypothesise that this result may be a good indicator that exercise through exergames has an optimal effect on the emotional state, as we have cleaner data because it is not influenced by the learning effect. In addition, it is however necessary to specify that significantly higher values in the pre-test elliptical may also explain the lack of significant effects in the post-test of this physical exercise. In fact, the higher values in the pleasure level and in the arousal level may have attenuated the possible positive effect of the aerobic exercise on the emotional state, resulting in the lack of a statistically significant difference between the two times of the experimental phase.

4. Limitations

This study has some limitations of a technical and design nature. First of all, the low sample size does not allow the results to be generalised to the reference population on the basis of age and schooling. Moreover, the research design is not fully adapted to the needs of this type of survey. In fact, the performance of the training is not counterbalanced, since the experimental procedure was carried out by presenting the two training sessions in the same order (the first day the exergames and the second day the elliptical). This methodological choice was influenced by the conditions imposed by the restrictions due to the Covid-19 pandemic. Consequently, the recruitment of subjects was conditioned by logistical factors that restricted the target group to female students participating in the study. Furthermore, the tests administered are the same for both trials, thus producing a learning effect that prevents the impact of each training on the domains under analysis from being adequately quantified. In fact, the short time interval between the two tests makes the cognitive tasks easier to solve in the second part of the experiment, since the participants have already had the opportunity to try the tasks the day before. It is therefore clear that it is necessary to interpret the data relative to the reaction times to the Stroop test and the responses to the logical-mathematical ability test as results necessarily affected by the learning effect which is not sufficiently mediated by the time elapsed between the two experimental sessions. Another important limitation of the study concerns the use of only the single-item scales of the Manikin Self-Assessment for the evaluation of the subjective emotional state. In fact, the analysis of pre and post-test emotional changes are difficult to quantify on the basis of the response to poorly structured stimuli and would require a more in-depth assessment.

5. Conclusions

The results obtained are the base for further considerations and perspectives. They allow us to outline several future directions of investigation. First of all, we propose to structure research projects on how to implement the teaching of physical education through exergames. In this sense, it would be useful to analyse the application of these types of video games in particular in the creation of specific educational paths for single motor domains to be trained, such as coordination and balance, with the aim of making the evaluation of student performance more accurate. In addition, evidence in the literature shows promising results with regard to the use of exergames in improving school performance through training that implements basic cognitive functionality. These impact on specific domains such as selective attention and executive functions, stimulating an improvement in the neural circuits underlying learning processes (Marasso, 2015; Xiong et al., 2019). Moreover, the possibility of programming exergames that can be customised according to needs opens the way to prospects of great interest in the educational field. Future research in this field of investigation could investigate the applicability of learning programmes built with the aim of fostering the acquisition of knowledge present in school curricula, working together with traditional teaching methodologies. In this sense, the creation of learning paths in which movement plays a prominent role, allows the direct involvement of neurobiological mechanisms related to the influence of certain types of movements on the mechanisms of knowledge acquisition. Therefore, the structuring of exergaming programmes created ad hoc on the basis of the subject in question, should take into account the implementation of movements directly related to the implementation of specific neural circuits, identified by the research carried out within the Embodied Cognition strand (Gordon & Ramani, 2021). The large number of possibilities of application of these tools in the clinical field, allow exergames to be identified as useful prevention tools. For example, balance training courses conducted through active games could be particularly useful to intervene early in balance disorders in children (Sgrò et al., 2017; Mombarg et al., 2013), with the prospect of being able to integrate such digital devices also in physical education lessons.

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