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Does the Use of Exergames Have a Positive Influence on Executive Functions and Academic Performance of School-Age Children with Specific Learning Disorder? A Literature Review

Veronica Tosta Coacci[1,2*], Fabrício Bruno Cardoso[1], Alfred Sholl-Franco[1,3], Cristiane De Carvalho Guimarães[2]

[1]Laboratory of Educational Innovations and Neuropsychopedagogical Studies (LIEENP), CENSUPEG, Joinville, Brazil
[2]Psychology Department, Estácio de Sá University, Rio de Janeiro, Brazil
[3]Núcleo de Divulgação Científica e Ensino de Neurociências (NuDCEN), Instituto de Biofísica Carlos Chagas Filho (IBCCF), Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, RJ, Brasi
Email: *veronicatostes@gmail.com

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Abstract

This research consists of an integrative literature review whose objective was to verify the effectiveness of neurorehabilitative and neuropsychopedagogical interventions using exergames to enhance the functioning of Higher Brain Functions, called Executive Functions, and to improve school performance in children with Specific Learning Disorders (SLDs), at school age, between 4 and 11 years old. The APA PsycNet, Nature, Springer, ScienceDirect, Pubmed, NIH, Researchgate, Scielo, Pepsic databases were consulted. Of the 154 articles initially selected, 6 were analyzed after passing the inclusion criteria, all of which were in English. All selected articles were published from 2000 onwards, being quantitative experimental studies. In all studies, the console used was Microsoft's Kinect Xbox or Nintendo Wii. Although the results cannot be generalized, the findings seem to point to the effectiveness of exergames as a neurorehabilitative and neuropsychopedagogical intervention and to an improvement in school performance in the case of Dyslexia and Dyscalculia, which are types of SLD. It was found that the production of knowledge on this subject is still incipient, with a lack of experimental research with a statistically representative sample size and a control group that remains inactive.

Keywords

Exergames, Neurorehabilitative Intervention, Neuropsychopedagogical Intervention, Executive Function

1. Introduction

In the last 20 years, a growing number of school-age children with deficits in language, attention, memory and motor skills have been observed in Brazil (Back et al., 2020). According to the American Psychiatric Association (2014), 5% to 15% of school-age children from different cultures and languages have a Specific Learning Disorder, with poor academic performance.

Executive Functions (EFs) are considered complex or superior mental functions and are responsible for self-regulation or self-management, reasoning skills, judgment, critical thinking, decision-making, concentration, planning, creativity and problem solving (Fuentes et al., 2014; Krause, Gasparini, & Hounsell, 2018).

Exergames or Active Games consist of a class of Digital Games (DG) in which the player's body movement performs actions within the game instead of using a joystick, as in traditional DGs (Mossmann et al., 2016). Some researches have been done in the last few years using exergames as a tool for neuropsychopedagogical or neurorehabilitative interventions.

Therefore, the aim of this work was to investigate, through an integrative literature review, the influences of exergames on the Executive Functions of school-age children (between 4 and 11 years old) with SLD and the possibility of using them as neurorehabilitative and neuropsychopedagogical intervention tools, as well as scientific evidence regarding the efficiency and effectiveness of these interventions to improve the functioning of the EFs and school performance.

2. Theoretical Framework

2.1. Executive Functions (EFs)

Anatomically, the Prefrontal Cortex (PFC)—tertiary portion of the frontal lobe—plays a key role in Executive Functions, although other neural circuits are also involved (Pires, 2010). It coordinates and integrates all other brain structures, which leads many authors to compare the PFC to a "conductor" or "executive director" of the human brain (Fuentes et al., 2014). The PFC is the last portion of the brain to mature, developing intensely between six and eight years of age, completing its development only close to 20 years of age, when there is a substantial improvement in information processing due to the end of the myelination process (Fuentes et al. 2014; Goldberg, 2002; Luria, 1981). This prolonged maturation process allows the child's interaction with its environment to shape the neural networks (Tonietto et al., 2011).

There is a certain consensus among specialists in dividing EFs into three basic, non-hierarchical functions: inhibitory control, working memory and cognitive flexibility (Diamond, 2013).

2.1.1. Inhibitory Control (IC)

Inhibitory Control (IC) is defined by many authors as the control that allows the subject to stop an action or impulse, which may have been conditioned or be the result of an internal disposition, to choose how to react appropriately to the demands that a given situation requires (Diamond, 2013, Zelazo, Blair, & Willoughby, 2016). Since IC is related to problem solving, reasoning and self-control, it plays a key role in students' academic performance (Mossmann, et al., 2016; Visu-Petra et al., 2011). Inhibitory cognitive processes are already in place by 12 months and continue to develop up to 6 years. Between 6 and 12 years old, children can demonstrate self-control, control of affections, control of motivation and well-being (Barros & Hazin, 2013; Smidts, 2003).

2.1.2. Working Memory (WM)

According to Gazzaniga, Ivry and Mangun (2006) memory is a nervous system's ability to storage knowledge and recover it later. The working memory (WM) would be a type of short-term memory whose purpose is to keep information evident and temporarily stored during the execution of the current task (Zelazo, Blair, & Willoughby, 2016). It lets you mentally reorder, compare, and update information. It is possible to store a sequence of actions to be performed, keeping the task steps (both those that have just been performed and the next ones) in the WM. It is an important component for reasoning, understanding and learning as when a reader has to integrate the various passages he has read into a cohesive and coherent idea or when a student has to store the intermediate results of a mathematical account until he arrives at the final result. WM is also essential for creativity, as it involves recombining information in a new way (Diamond, 2013).

2.1.3. Cognitive Flexibility (CF)

Cognitive Flexibility (CF) is the ability to think about a situation, object or concept from different perspectives so that the person adjusts to the demand, modifying thought/behavior patterns and recreating scenarios. CF develops more intensely between 6 and 10 years of age (Barros & Hazin, 2013; Smidts, 2003), and is built from Inhibitory Control and Working Memory, being more complex than the latter. It allows us to move between simultaneous tasks and reflect on complex situations, such as when we imagine a geometric figure being rotated in another direction, when we try to understand the situation from the perspective of another person or when we admit that we are wrong (Diamond, 2013; Zelazo, Blair, & Willoughby, 2016). Difficulties in CF are observed when the subject perseveres in an answer that has already proved to be wrong, or when he cannot disregard some hypothesis (Gazzaniga, Ivry, & Mangun, 2006). There is an improvement in planning tasks, cognitive flexibility and verbal fluency between 4 and 5 years old and problem solving between 7 and 9 years old (Barros & Hazin, 2013; Smidts, 2003).

2.2. Specific Learning Disorder (SLD)

Specific Learning Disorder (SLD) is a neurodevelopmental disorder of neurobiological origin that affects mathematical, reading, writing or reasoning skills that translate into poor school performance (Back et al., 2020; Pinheiro et al., 2018). The American Psychiatric Association (2014) states that the biological origin includes an interaction between genetic, epigenetic and environmental factors that influence the brain's ability to perceive or process verbal or non-verbal information. The individual's academic abilities and performance are below expectations for the individual's chronological age, without another mental disorder, psychosocial adversity, or lack of proficiency in the language of instruction to justify the difficulty. Learning problems are persistent and are not just a result of a lack of learning opportunities or poor education. They must persist for at least 6 months, after initiation of appropriate educational interventions. As in other neurodevelopmental disorders, it is more common in boys than in girls (Chung, Patel, & Nizam, 2020).

Specific Learning Disorders are often confused with laziness or a student's cognitive deficit, not being properly diagnosed and treated. Which leads to problems of low self-esteem, depression or aggressive behavior in the child. All SLDs can be comorbid with other Neurodevelopmental Disorders such as Attention Deficit Hyperactivity Disorder (ADHD) or Austite Spectrum Disorder (ASD) (Chung, Patel, & Nizam, 2020).

2.2.1. Dyslexia

Learning to read is extremely difficult for approximately 10% of children as they are affected by an inherited neurobiological disorder called Dyslexia (Finn et al., 2014). This Specific Learning Disorder is characterized by impaired word recognition, which may involve fluency, decoding and spelling problems (AMERICAN PSYCHIATRIC ASSOCIATION, 2014).

Some dysfunctions are usually present in Dyslexia, such as deficits in the perception of sound in the auditory cortex, phonological awareness and processing of letter identity and coding of its location (Finn et al., 2014). Subjects with Dyslexia have less activation of the left temporal cortex and the left fusiform gyrus during reading. This disorder presents itself as lower accuracy and speed of reading. Unfortunately, there is no "gold standard" treatment for dyslexia, but it requires intensive sessions and explicit instructions for exercises done individually or in small groups (Peterson & Pennington, 2012). All standard methods of classic treatment include exercises with pencil and paper that tend to arouse little motivation for dyslexic children, who end up having difficulties to complete the treatment (Franceschini et al., 2013). Attention seems to be involved in Dyslexia, one of the hypotheses is a deficit in identifying the order of tones presented quickly and difficulties during the scanning of letters when there are distractors during the process (Pedroli et al., 2017).

2.2.2. Dyscalculia

It is estimated that 3% to 7% of all children and adolescents suffer from dyscalculia. Poor mathematical skills are associated with a large psychosocial and economic risk: 70% to 90% of those affected drop out of school at age 16, and by age 30 few are employed full time and are twice as likely to develop depressive symptoms (Parsons, & Bynner, 2006).

According to the American Psychiatric Association (2014), dyscalculia is an SLD characterized by difficulties in processing numerical information, learning arithmetic facts and performing accurate or fluent calculations. The first signs of dyscalculia can be noticed already in preschool, such as delays in learning to count and use arithmetic strategies, followed by a persistent difficulty in remembering arithmetic facts. Children between 8 and 10 years old with Dyscalculia are slower to count and enumerate groups of up to 4 objects (Koontz, 1996; Haberstroh & Schulte-Körne, 2019). There is also a deficit in the understanding of numerical magnitudes, the position that a number occupies in relation to others, and less efficiency in the approximation calculation and automatic processing of numbers (Rousselle & Noel, 2008). A deficient representation of "number sense" has been proposed as an explanation for Dyscalculia. This ability is in the region of the intra-parietal sulcus, as far as is known, and is proposed to be responsible for the representation of numeric semantics (Haberstroh & Schulte-Körne, 2019). Treatment should be individualized, using scientifically proven techniques and conducted by specialized professionals (Wilson et al., 2015).

2.2.3. Dysgraphia

Dysgraphia is a Specific Learning Disorder that affects written expression, impairing spelling, grammar, punctuation and clarity and organization of writing (American Psychiatric Association, 2014). Dysgraphia includes problems with letter writing and/or legibility, letter spacing, spelling, grammar, composition, fine motor skills and writing speed (Chung, Patel, & Nizami, 2020).

The genetic transmission of writing and reading disorders has been confirmed by twin studies. Some genes have been studied as a possible cause of Dysgraphia and Dyslexia, and a gene on chromosome 15 has been identified as related to reading problems (Berninger, 2008; Chung, Patel, & Nizami, 2020). Problems in reading, writing and counting skills may also be related to a delay in the development of systems that integrate complex cognitive functions, leading to disharmonious maturational development between some cortical systems, such as the graphomotor loop that associates sounds with phonemes, and the working memory (Berninger, 2008; Zoccolotti & Friedmann, 2010). Between 30 and 47% of children with Dysgraphia have Dyslexia, which is also related to deficiencies in the phonological loop, but in two circuits, which communicate between orthographic and phonological processing (Chung, Patel, & Niami, 2020).

Writing is a complex process with many steps such as mentally creating the sentence you want to write, breaking it down into smaller parts that will be stored in the WM, activating the long-term spelling memory to create an abstract representation of the letter that will be part of the execution plan of the motor action that will be kept in the WM during the execution of the task. Fluidity in writing requires planning and motor coordination mediated by the cerebellum. During the execution of the entire task, visual and auditory processing and attention are crucial to produce legible writing. Different writing tasks will require different brain systems, and a failure in any one of them will lead to problems in writing. Recent studies have shown that all dysgraphia "types" are related to problems in the areas of automaticity, language and motor coordination. Research has shown that motor skills training in conjunction with spelling training is the most effective approach. There is evidence that games and educational activities help students store letters in long-term memory (Berninger, et al., 2006; Hung et al., 2020). Children with Dysgraphia usually have a great aversion to writing, leading therapists to start treatment with simple exercises that train primitive writing movements, which gradually evolve into more complex exercises (Biotteau, 2019).

2.3. Digital Games (DG)

Schell (2015) in his book on Game Design says that Digital Games (DG) are just an evolution of board games and other children's games, having the same attractions as the latter, such as the challenge of solving a problem and the opportunity of player exercise certain skills. If there is an appropriate match between the player's skill level and the game's difficulty level, the player will feel challenged and remain in a state he calls "flow" or immersion (Hira et al., 2016; SchelL, 2015). The psychologist Csikszentmihalyi (2014) who studied this state of consciousness states that it would be associated with human happiness, and that it can be explained as a state of sustained attention that involves feelings of pleasure and fun. It's the moment when all you're thinking about is what you're doing, to the point where you lose track of time.

The purpose of construction of the DG can be casual, made just for entertainment or for learning (also called "serious game"), when it is designed for learning and developing specific skills (Connolly et al., 2012).

Exergames

A specific type of video game where the player needs to coordinate the movement of various body parts to control game elements using some form of motion detection has been called "Exergame". Some examples available on the market are the Nintendo Wiimote and the Microsoft Kinect (Di Tore & Raiola, 2012).

The study by Finco et al. (2015) points to a greater motivation of students to practice physical exercises when using exergames in Physical Education classes. More frequent players of exergames seem to have an increased state of flow, adding to these the physical, psychosocial and cognitive benefits of continued practice (Lai, Wang, & Yang, 2012).

Exergames and Rehabilitation of Children with Learning Disabilities

Diamond's work (2013) states that it is possible to stimulate and improve the EFs of subjects (including children) by making their behaviors more adaptive to everyday situations. Luria (1981), one of the founders of neuropsychology, already commented decades ago that, due to the PFC being the least differentiated and organized structure of the cerebral cortex, its individual zones could be replaced.

Diamond (2015) states that the EFs and the Prefrontal Cortex, on which they depend, are more impacted when we are sad, stressed, lonely, without adequate sleep or sedentary. It is suggested that an improvement in the practice of physical activity combined with a diversified EFs training, which at the same time brings pleasure and a sense of social belonging, would bring a substantial improvement in the EFs of children (Mossmann et al., 2016).

Studies have observed that exergames can train specific EFs by changing the complexity of certain parameters such as speed and game rules (Best, 2012; Fronza et al., 2020). Exergames combine cognitive and physical challenges, which creates a dynamic need to switch between concentrated and divided attention (Gashaj et al., 2021). Mura et al. (2018) explains that exergames fit many of the principles of experience-dependent neuroplasticity (Kleim & Jones, 2008), such as high-intensity repetition of task-oriented exercises, tasks with incremental difficulty, real-time feedback, salience, motivation and reward, and even transferring performance improvement from a task that was trained to another that was not (Mura et al., 2018). The study by Staiano, Abraham & Calvert (2012) that compared the performance of children in a control group with a group that played a cooperative exergame and another, a competitive one, concluded that competition demands much more from the PreFrontal Cortex because the competitor needs to mentalize your own information and that of the other in order to win.

Studies on the feasibility of using exergames as an alternative or complement to traditional rehabilitation that can be performed at home have been done. Exergame therapies can serve as a complement to traditional interventions, increasing the intensity and quantity of training without interfering too much with the family routine (Gerber, Kunz, & van Hedel, 2016). Children with different types of disorders, such as dyslexia, spend much more time playing sedentary video games than children with typical development (He et al., 2014). The physical and cognitive benefits are of paramount importance because they are related to the improvement in academic performance (Staiano & Cavert, 2011). Another advantage is high scalability and cost-effectiveness.

There are several technologies that capture motion, each with its drawbacks. The user can "cheat" in some cases, making the sensor detect a movement of body parts that are not actually moving (Baranowski et al., 2014). Technological difficulties can also lead to withdrawal from training (Benzing & Schmidt, 2018). Many exergames available on the market may not be appropriate for children with deficits, as they have a cognitive load that is incompatible with the demands of children with such problems, and a very complex gameplay (Caro et al., 2015).

It is worth mentioning that many exergames have been developed for diagnosis. One of the first programs for mobile applications that uses Artificial Intelligence to track and intervene in SLDs (Dyslexia, Dysgraphia and Dyscalculia) called "Pubudu" was developed. Pubudu was tested on 50 children with SLDs studying in special schools in Sri Lanka. Interventions were implemented using gamification techniques. An accuracy of 88% to 90% was obtained in the detection of Dysgraphia, Dyslexia and Dyscalculia (Kariyawasam et al., 2019). Some apps where the user writes with tablet pens have been developed to diagnose Dysgraphia by analyzing the user's handwriting (Dui, 2016). A study in France with a sample of 242 children, of which 56 had Dysgraphia obtained a diagnostic accuracy comparable to that of specialists (Asselborn et al., 2018).

3. Methods

The bibliographic survey conducted resulted in a total of 154 articles found. The primary reading of titles and abstracts was performed on 75 pre-selected articles. Subsequently, additional inclusion and exclusion criteria were applied in order to select only those articles that potentially responded to the objective of this review, reaching the end of only 6 articles, all in English. The following databases were consulted: APA PsycNet, Nature, Springer, ScienceDirect, Pubmed, Nih, Researchgate, Scielo, Pepsic. Considering the difficulty in identifying precise descriptors for the term "Exergames executive functions children with learning disorder", the following terms were chosen, as they result in a greater number of documents related to the investigated theme: "Exergames executive functions children", "exergames rehabilitation neuropsychological children", "exergame dyslexia", "exergame dysgrafia", "exergame dyscalculia". While reading the articles, it was observed that most of the studies were done with two commercial exergames: the Wii and the Xbox Kinect, sometimes without explicitly mentioning the word "exergame". In this way, the descriptors "kinect dyslexia", "kinect dyscalculia", "kinect dysgrafia", "wii dyslexia", "wii dyscalculia", "wii dysgrafia" were added later. The Boolean operator AND was used in all databases, connecting the selected terms and only one search limit was considered: articles indexed in the period between the years 2000 and 2022.

Inclusion criteria were: Experimental or quasi-experimental researches, studies evaluating EFs with exergames in children with Specific Learning Disorder (SD), studies evaluating exergames that trained skills and subfunctions of the EFs affected in people with SLD, studies carried out with children between 4 and 11 years old, studies published in Portuguese and English. Exclusion criteria were: studies that did not mention any type of exergame, studies that only tested the usability of a developed exergame, studies on the influence of exergames only on motor skills, studies investigating the influence of exergames on EF components other than those of involved in TAs, repeated articles. The article selection process is summarized **Figure 1**.

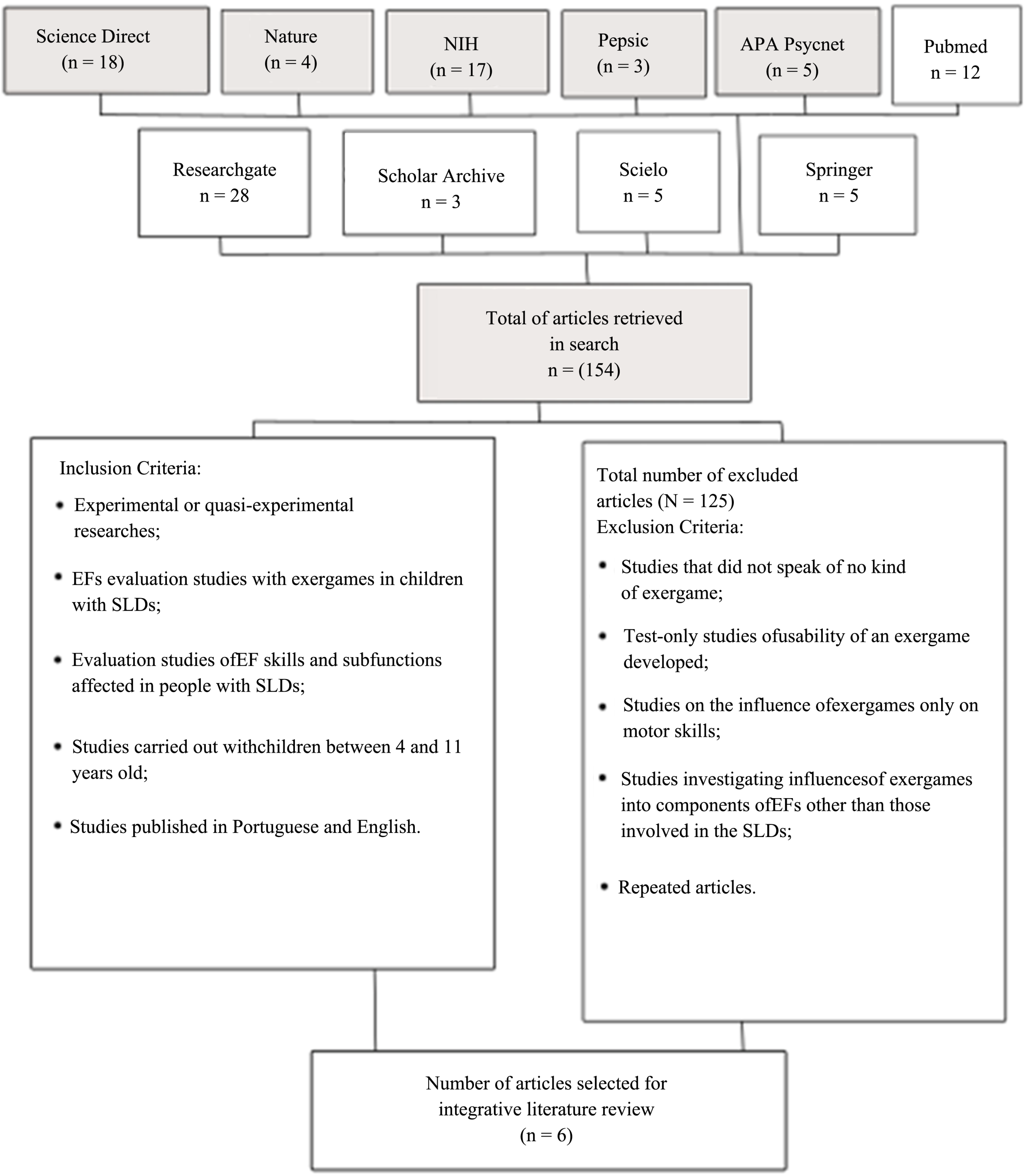

Figure 1. Flowchart of the number of articles found and selected after applying the inclusion and exclusion criteria.

4. Results

The sample was then composed of 6 articles, all in English, about the relationship between exergames and the EFs of children with SLD. A spreadsheet was organized for data extraction, with the characteristics of the studies and their main findings, which is presented in Table 1.

Table 1. Variables analyzed from the studies found.

Reference	Country	Objective	Method	Sample	Main Results
Franceschini et al., 2013	Italy	To determine the association between phonological and text reading skills in children playing an Action Video Games (AVG).	The entire sample received training with a commercial Wii game (Rayman Rabbids), with training sessions of 80 minutes a day, totaling 12 hours. Half received training with a Rayman Rabbids' minigame of action (AVG) and the other half with a non-action (NAVG) minigame.	N = 20, children with dyslexia and mean age between 9 and 10 years old	Evidence of increased reading speed without any impairment in accuracy) and improvement in attentional skills in training with AVG compared to NAVG.
Łuniewska et al., 2018	Poland	This research aimed to retest the study by Franceschini et al. (2013) that evaluated the improvement in reading performance of dyslexic children with a training with an action exergame, with a larger sample and with a control group, only changing the group that played exergame without action (NAVG)	The training group with non-action exergame (NAVG) consisted of 6 minigames developed especially for the research, with phonological training activities without any characteristic of action games. The AVG group received training with the Wii game (Rayman Rabbids), exactly as in the previous survey. The control group received no training.	N = 54, children with dyslexia, mean age 11 years, 18 boys	No evidence of improvement was found in relation to the control group.
Pedroli et al., 2017	Italy	To evaluate improvement in attention and reading skills in dyslexic children with training with developed exergame.	The entire sample received 30 to 45 minutes of training per day twice a week for 4 weeks. The game contained attention, reading and phonological activities.	N = 10 with dyslexia (2 girls and 8 boys) and aged between 9 and 12 years.	No improvement in reading performance was observed.
Cress et al., 2010	Germany	To compare the performance of preschool children who played psychopedagogical games for learning numerical quantities with children who did not play.	Half of the children were trained with a dance mat game in 3 sessions, and the other half with a tablet game. All items were presented twice.	N = 19 preschool children (8 girls and 11 boys) aged between 60 and 79 months	There was a greater effectiveness of the dance mat game compared to the simple tablet game.
Alzubi et al., 2018	Spain	Evaluate the performance of children from a rehabilitation center in mathematical skills when playing an exergame for Kinect.	The experiment was conducted with preschool children in Spain, who were divided into a control group and an experimental group that trained for 30 minutes, 3 times a week for 4 months. The exergame for Kinect consisted of 9 minigames that stimulated the learning of numbers, quantity and ordering.	N = 60 preschool children between 5 and 6 years old.	Significant improvement in working memory and basic math skills compared to children who performed normal school activities.

Continued

Cancer et al., 2020	Italy	Comparing the performance of a training session with a computerized Rhythmic Reading intervention Training (RRT) with another group and combined a traditional treatment called Bakker's Visual Hemisphere-Specific Stimulation (VHSS) with AVG training	Half of the sample went to the RRT group and the other to the VHSS-AVG group, which, as in the experiment by Franceschini et al. (2013) used action minigames from the Wii game "Rayman Raving Rabbids". All received 45 minutes of training for 9 days.	N = 24 students with dyslexia, between N = 24 students between 8 and 14 years old	The RRT group had a slightly greater improvement in reading speed, and the VHSS-AVG group a greater improvement in reading accuracy. Significantly greater improvement of pseudoword reading in the RRT group.

5. Discussion

Franceschini et al. (2013) is one of the most influential and referenced in regard of exergames and SLDs. Their research was carried out with children diagnosed with Dyslexia, half of the sample received training with an action video game (Action Video Games, AVG) and another with a non-action game (NAVG), both games were part of a Wii's game called Rayman Rabbids. Their study concluded that training with AVG improves the efficiency not only of visual processing but also of auditory and multimodal processing (Franceschini et al., 2013). Action video games (AVG), already studied in previous works, seem to improve visual perception and attention (Green & Bavelier, 2003; Li et al., 2010). Franceschini & Bertoni (2019) note that phonological decoding speed and short-term phonological memory are improved only in children with Dyslexia who have improved their scores in AVG training.

Łuniewska et al. (2018) set out to replicate the study by Franceschini et al. (2013). They points out some problems with the original study: a small sample size, which prevents generalizations of the findings, and the lack of a control group that had not received any type of training. Therefore, some changes were made in their study: The research was carried out with a larger sample of participants (54 children with Dyslexia), with a control group that in fact did not receive any type of activity, and a modified Non-Action VideoGames (NAVG) training group. Training for the AVG group was exactly the same as in the original study, but for the NAVG group, six minigames were developed that contained phonological training activities, without any component of action games. Research concluded that AVG and phonological training improve reading by improving visual attention and reading fluency. Reading speed, accuracy, phonological awareness, selective attention, and rapid naming improved in both the AVG and NAVG groups. But surprisingly, the control group also got similar results. Therefore, Luniewska et al. (2018) concludes that the improvement observed in the experiment by Franceschini et al. (2013) may have been due to the small sample size, or to an improvement that naturally occurs with development, schooling or learning effects on tests (Luniewska et al., 2018), contradicting the original findings.

Studies developed on this subject have brought several important contributions regarding the best forms of treatment for Dyslexia. Hubert-Wallander et al. (2011) observe that in visual scanning tasks in complex scenarios, as in the case of a letter among twenty distractors, AVG players perform better than non-players. In tasks where participants only had to count the number of dots on a screen, children with Dyslexia performed poorly, especially with large amounts (Eden et al., 1995; Wilson et al., 2015). It is precisely in this type of task that AVG players perform better than non-players (Green & Bavalier, 2003). By providing extra wide spacing between letters and words, thus reducing the agglutination effect, it also seems to improve the accuracy and reading speed of children with Dyslexia, in real time, without any previous training, according to several works (Zorzi et al., 2012; Spinelli et al., 2002; Moores, Cassim, & Talcott, 2011; Cassim, Talcott, & Moores, 2014). AVG players showed a significant reduction in the agglutination effect compared to non-players after 20 hours of training (Green & Bavalier, 2007).

The research by Alzubi et al. (2018) despite not have been carried out with typical children, without including any group of children with Dyscalculia, used a control group, which did not participate in any video game training, and a relatively large sample, compared to other recent studies. Their positive results on WM and children's math skills compared to the control group are promising.

The study by Cress et al. (2010) was done with a small sample (19 preschool children) of typical children, and without a control group. The research design was implemented so that half of the sample trained with a math education game for tablets, and the other half of the sample participated in training with a dance mat game in which the child did activities to learn and fix the idea of numerical quantities and other mathematical concepts using the body's own movement on the mat. This research concludes that the mental representation of numerical sequence and magnitude is more strongly activated when the presentation and format of numbers has more stimuli. The spatial stimuli of movements on the mat that represented the numerical sequence and the spatial position of the number contributed to the perception and memorization of the idea (Cress et al., 2010). On the tablet the numbers were presented without any external representation. As the spatial representation of numeric magnitude is a basic competence that predicts learning in mathematics (Booth & Siegler, 2008), training this skill can be beneficial for preschool children, in addition to being extremely motivating. This study supports the idea that the inclusion of the representation of abstract concepts through bodily experiences can help in the acquisition of knowledge (Cress et al., 2010).

No studies were found involving exergames in the stimulation and rehabilitation of children with Dysgraphia that met the inclusion criteria of this research. However, it is worth mentioning the preliminary study by Loup-Escande et al.

(2017) that was done with software for tablets that uses a pen, to analyze gestural performance during writing. This research was done with typical adults, therefore it was excluded in the criteria of this integrative review.

6. Conclusion

The results on the improvement in EFs after training with exergames, and consequently on the school performance of children with Specific Learning Disorder, are still controversial, mainly in the case of Dyslexia. There are few studies on this disorder, and among them those that point to the effectiveness of exergames as a neuropsychopedagogical and neuropsychorehabilitative tool have a poor experimental design. The only more robust research found pointed in the other direction: there was no improvement in playing exergames for children with dyslexia. Therefore, we cannot currently draw conclusions about exergames improving EF in dyslexic children.

Studies using training with exergames in children diagnosed with Dyscalculia were not found. Further research with a larger sample, control group and a group of children with Dyscalculia is necessary.

Experimental research comparing children with Dysgraphia and typical children in training with exergames was not found. The lack of work in this area points to the need to assess exergames to train the writing of typical and atypical children.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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