

A Systematic Review of Literature on Emerging Technologies and Specific Learning Difficulties

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Abstract: Educational research on emerging technologies, particularly virtual reality and augmented reality, is expanding at the moment. The purpose of this contribution is to conduct a systematic review to understand the impact of emerging technologies in the educational and social-health fields. The PRISMA 2020 methodology was used to respond to the objective and research questions, ensuring the fulfillment of the quality criteria in the elaboration of the systematic review. This systematic review analyses the possible benefits that new technologies, specifically virtual reality and augmented reality, can have on learning difficulties such as dyslexia and ADHD disorder, as well as their inclusion in the social sphere. In this study, articles from both the health and educational fields will be reviewed. The research focuses on highlighting the incipient benefits of these new technologies for the aforementioned learning difficulties in the school and health fields. The main conclusions drawn show that research on these emerging technologies is still scarce and incipient in the educational field, with the main results found in the healthcare field.

Keywords: systematic review; specific learning disabilities; specific learning disorders; dyslexia; attention deficit hyperactivity disorder (ADHD); virtual reality (VR); augmented reality (AR)



Citation: Lozano-Álvarez, M.; Rodríguez-Cano, S.; Delgado-Benito, V.; Mercado-Val, E. A Systematic Review of Literature on Emerging Technologies and Specific Learning Difficulties. *Educ. Sci.* **2023**, *13*, 298. <https://doi.org/10.3390/educsci13030298>

Academic Editor: James Albright

Received: 17 December 2022

Revised: 8 March 2023

Accepted: 9 March 2023

Published: 13 March 2023



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1. Introduction

“Specific Learning Disabilities”, specifically dyslexia, refers to a series of disorders characterised by difficulties in listening, speaking, reading, writing, and reasoning that are unique to the individual and are due to an alteration and/or dysfunction of the central nervous system [1].

According to the DSM V, specific learning disorders or specific learning difficulties are neurodevelopmental conditions, which means that they have a genetic origin and a cognitive-behavioral expression that depends on the environment [2]. Concerning its causes, the most widespread opinion among experts is that there are multiple causes to explain its origin. There are two types of etiological explanations, the first related to historical approaches and the second to environmental factors [3].

From an etymological point of view, dyslexia means difficulties with words, with language (from the Greek dys-: difficulty, poor, bad, inadequate ... and lexis: words or language).

Therefore, it is not only about the problem affecting reading but can also allude to other aspects of language, such as spelling [4]. It is now known to be a congenital and developmental condition, although the causes are not fully confirmed.

Research such as that of Forteza et al. has pointed out that between 5% and 15% of the school population suffers from this difficulty [5]. In Spain, it has an impact between 5% and 10% in primary and secondary education [6]. We found that this difficulty has a very relevant incidence of students in the education system.

According to Zuppardo et al., the effects of this learning disorder are not as severe as initial research suggested, even though it causes serious difficulties in the positive

development of learning during childhood and adulthood. It disrupts not only students' learning but also their cognitive and emotional development. Children with this learning difficulty frequently have low self-esteem, as well as reduced social-emotional behavior and anxiety [7].

Therefore, education needs to find up-to-date solutions that help students and teachers recognize, detect, and overcome learning difficulties. One solution that significantly increases learners' motivation is to combine the adoption and promotion of universal design for learning (UDL) with information and communication technologies (ICT) [8].

"Specific Learning Disorders", specifically attention deficit hyperactivity, is determined by the presence of three fundamental symptoms: decreased attention, impulsivity, and hyperactivity [9].

According to the DSM V, attention deficit disorder with or without hyperactivity disorder, is a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning, development, or daily activities. There are three types: inattentive, hyperactive-impulsive, and combined inattentive/hyperactive-impulsive [2].

Regarding the prevalence of ADHD, worldwide it is around 7% of children and adolescents. In Spain, it has an incidence of 5.4%, with high rates of associated comorbidity and a significant impact on school performance and family health [10]

Educational, psychopedagogical, and speech therapy interventions are essential for students who present these difficulties such as dyslexia and ADHD. In this regard, in recent years, several studies have shown that these disorders have important consequences on students' academic results, which can lead to school failure and early leaving [11–13].

According to the educational legislation in Spain, Organic Law 3/2020, of 29 December, which amends Organic Law 2/2006, of 3 May, on education, also known as the LOMLOE law, amended Article 71(1) and (2) to read as follows [14,15]:

1. "The educational administrations shall provide the necessary means for all pupils to achieve the maximum personal, intellectual, social and emotional development, as well as the objectives established in general terms in this Law".
2. "It is the responsibility of the educational administrations to ensure the necessary resources so that pupils who require educational attention different from the ordinary one".

European legislation in general is committed, as is Spanish legislation, to equity, methodological flexibility, and an increase in economic resources to improve school failure rates. The European Commission identifies inclusive education as a priority, as well as the importance of promoting social inclusion through formal and non-formal learning, which translates into the development of social and educational policies by European institutions [16]. On the other hand, it should be noted that UNESCO's 2030 agenda for sustainable development [17] expressly mentions inclusion and social cohesion as keys to inclusive social development.

The incorporation of information and communication technologies (ICT), educational technology (ET) design, and software development in the educational field contributes to school intervention, offering playful and effective environments for the treatment of different disorders in children and adolescents [18,19].

In recent years, different emerging technologies are emerging in the educational field, in which research must provide light and pedagogical possibilities to be able to integrate its functionalities into the daily life of the classroom [20]. Within the technological field, virtual reality and augmented reality can make important contributions to the treatment of specific learning difficulties, since they offer more playful environments that can improve adherence to treatment as well as safe and controlled environments in which failure does not have negative consequences for the student [21].

Augmented reality (AR) is the technology that allows combining real and virtual objects in the same environment and executing them interactively in real-time. This technology allows the visualization of the real environment that is augmented by elements or objects generated by a computer or mobile device [22]. One of the elements that make

this technology more attractive is the simplicity in handling because it can be used with devices that most of the population has at its disposal and because there are numerous unsophisticated applications from which these objects and experiences can be created and disposed of in AR [23].

On the other hand, virtual reality (VR) is an emerging technology in recent decades, becoming in the last fifteen years a powerful educational element and a tool for evaluation and intervention in the school environment. This interest is confirmed in research such as that carried out by Aznar et al., who conducting a review of the state of scientific literature in Spain, conclude that there is a growing interest in this technology and its implementation in the educational field since 2015 [24]. Virtual reality (VR) can be defined as the technology that allows users to immerse themselves in three-dimensional scenarios in first person and 360 degrees, favoring their immersion in interaction with a different reality and the elements that compose it [25].

Both technologies are characterized by being immersive, generating motivation, allowing interaction, transduction (user access to virtual stimuli), as well as the inclusion of 2D and 3D virtual models. All these elements enable its application in the educational field since they offer more playful, safe and controlled environments [25].

The versatility offered by these emerging technologies makes them adaptable to different contexts; one of them is the attention to diversity such as dyslexia and ADHD [21]. In this sense, research has shown that the acquisition of knowledge improves as a result of the implementation of these technologies in the classroom, greatly enriching the educational experience as well as the academic results of these students [20,26].

2. Purpose and Objectives

To respond to the objective and research questions, a systematic literature review methodology was followed [27]. To ensure rigor and meet certain quality criteria, a series of standardized phases have been developed in the preparation of the systematic review and it has been developed considering the quality standards of the PRISMA [28].

The general objective of the article is to learn about the influence of emerging technologies in the educational and socio-health fields.

The purpose of the systematic review is to analyze other research related to specific learning difficulties and Specific Learning Disorders and the use of emerging technologies, namely virtual reality and augmented reality. Its aim is to identify and compile the benefits of using emerging technologies for students with specific learning difficulties at school. To this end, the following research question is addressed: "Do Virtual Reality and augmented reality have any academic benefits for students with Specific Learning Difficulties?".

3. Method

To conduct the systematic review, a literature search was conducted, identifying the main descriptors (keywords), inclusion and exclusion criteria as well as the creation of a data collection form to ensure a rigorous systematic search process.

In this regard, we have used the statement preferred reporting items for systematic reviews and meta-analyses (PRISMA), designed to help systematic reviewers transparently report why the review was conducted, what the authors did and what they found [28]. Over the past decade, advances in systematic review, methodology and terminology have necessitated an update of the guideline, advancing methods for identifying, selecting, evaluating, and synthesizing studies using a checklist of 27 PRISMA 2020 elements [29].

The PRISMA statement has been designed primarily for systematic reviews of studies assessing the effects of health interventions, irrespective of their design. However, the topics in the checklist apply to publications of systematic reviews that evaluated other non-health interventions (e.g., health interventions, social or educational interventions) [29].

4. Procedure

Between September and October 2022, a review of scientific articles was conducted, collecting current publications, specifically those published in the last 5 years and related to specific learning difficulties, ADHD, Dyslexia, virtual reality, and augmented reality. The multidisciplinary databases Web of Science and Scopus were used in the bibliographic search process, as they are the most commonly used in the field of social sciences due to their scientific rigor.

On the other hand, to further refine the search and define the relationships and combinations between descriptors, Boolean operators (AND, OR, NOT) have been used. Table 1 lists the descriptors and Boolean operators used in the document search.

Table 1. Descriptors (keywords) and Boolean operators used in the search.

English descriptors
learning AND difficulties OR learning difficulties AND virtual reality OR learning difficulties AND augmented reality OR adhd AND augmented reality OR adhd OR adhd AND virtual reality OR dyslexia AND augmented reality OR dyslexia OR dyslexia AND virtual reality OR virtual reality OR augmented reality
Spanish descriptors
dificultades AND aprendizaje OR dificultades AND aprendizaje AND realidad virtual OR dificultades AND aprendizaje AND realidad aumentada OR tdah AND realidad aumentada OR tdah OR tdah AND realidad virtual OR dislexia AND realidad aumentada OR dislexia OR dislexia AND realidad virtual OR realidad virtual OR realidad aumentada

After identifying the descriptors, inclusion and exclusion criteria were then established in order to clarify the search in the databases and to determine the articles published in scientific journals of a more notable and useful nature in relation to the subject to be dealt with.

The inclusion and exclusion criteria established for the selection of articles were as follows:

Inclusion criteria:

- Articles published between 2016 and 2022.
- Articles published in English and Spanish.
- Articles examining the feasible use of virtual reality and/or augmented reality for students with specific learning difficulties.
- Articles published in scientific journals only.

Exclusion criteria:

- Non-educational articles.
- Articles with insufficient data for meta-analysis.

A virtual intelligent systematic review system (Rayyan) was used to select the articles. This tool allows you to store the bibliographic search and then, depending on the search criteria, to select the articles. Table 2 shows the systematic review used, and the selected studies are listed in Table 3.

Table 2. Research articles selected on the basis of the study population.

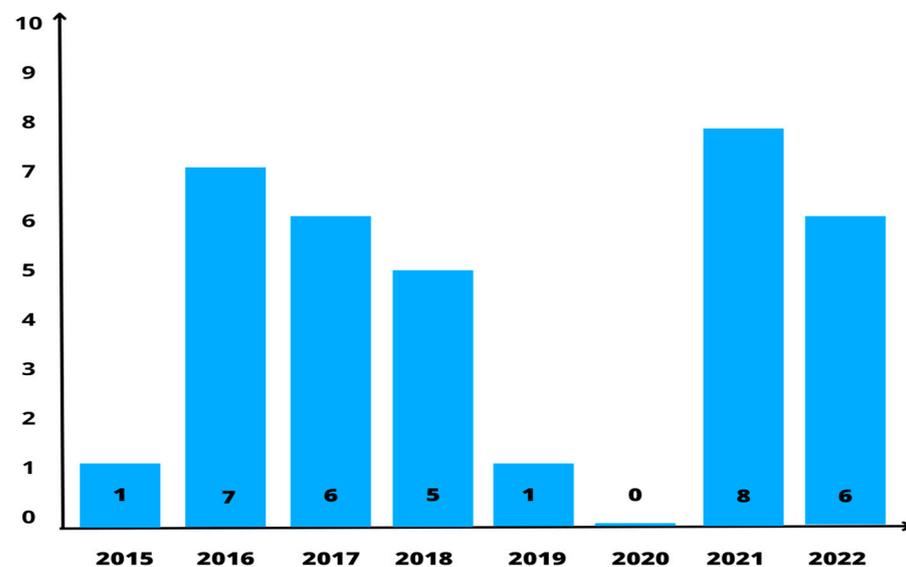
	n
Adults	12
Children and adolescents	18
Professionals	3
Parents and/or guardians	1

Table 3. Results of systematic reviews.

Systematic Reviews		
Author(s) and Year	Population	Summary Keywords
De-La-Peña Álvarez, C. et al. (2018) [6]	Professionals	Learning difficulties and dyslexia.
Minguillon, J. et al. (2022) [30]	Adults	Virtual reality
Palacios-Navarro, G. et al. (2016) [31]	Adults	Disorders and virtual reality
Riva, G. et al. (2016) [32]	Adults	Virtual reality, augmented reality, and medicine.
Urchaga Litago, J.D. (2017) [33]	Adults	Dyslexia and ADHD
Van Dun, K. et al. (2018) [34]	Professionals	Brain and cognition.
Vanderwal, T. et al. (2022) [35]	Children and Adolescents	Nervous System, brain, and cognition.
Yadav, D. et al. (2021) [20]	Professionals	BCI devices and medical applications.

5. Scientific Production and Target Population

In terms of scientific production, the basis of the study corresponds to 11.81% of the total articles selected on the subject in the different databases used (Web of Science and Scopus). Figure 1 shows the selected scientific articles by year.

**Figure 1.** Selected scientific articles.

In relation to data processing, a work of analysis and synthesis has been carried out on all the information obtained to arrive at a current study. On applying the inclusion criteria, 34 articles were obtained. Figure 2 shows a diagram of the selection procedure for scientific articles related to the topic to be addressed.

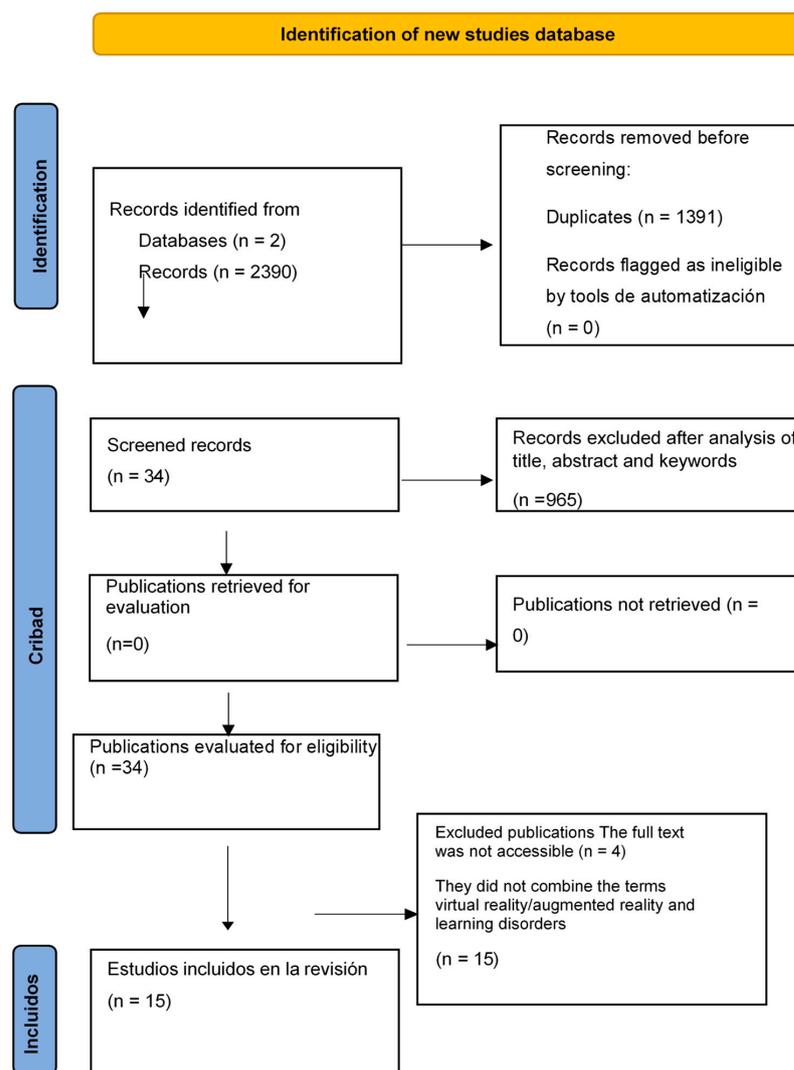


Figure 2. Study selection diagram.

6. Population

In terms of the study population, we found diversity in the different research articles selected. As can be seen in Table 2, the child and youth population predominates over the rest ($n = 18$).

The research studies selected in this systematic review were published mostly in 2021, being in reviews ($n = 1$) and studies ($n = 7$), both in 2022 and 2017 the same number of studies ($n = 6$) and different number of reviews, in 2017 ($n = 1$) and in 2022 ($n = 2$) and finally in 2016 in reviews ($n = 2$) and studies ($n = 5$).

The target population is mostly children and adolescents ($n = 18$), adults ($n = 12$), and is scarcer in professionals ($n = 3$) and especially in parents ($n = 1$).

7. Results

Information on the Studies

In order to analyze the data from the selected research articles, a process of meaningful data extraction has been conducted:

Author(s); year of publication; target population; sample; and type of study. In the case of revisions, they are shown: Author(s); year(s) of publication; target population; and key words from the abstract of the article.

Table 3 shows the results of systematic reviews and Table 4 shows the results of studies.

Table 4. Results of the studies.

Studies			
Author(s) and Year	Population	Sample	Type of Research
Aborokbah, (2021) [36]	Children with dyslexia	Children with dyslexia	Critical study
Areces, D. et al. (2018) [37]	Children with ADHD	Children aged 6–16 years	Evaluation study
Arroyo-Ferrer et al. (2021) [38]	Adults with cognitive sequelae	1 student	Case study
Cuesta et al. (2016) [39]	Children with ASD	Children with ASD	Empirical-explanatory study
Fernández-Caballero et al. (2017) [40]	Persons with physical and mental disabilities	Researchers and physicians	Normative study
Freeman et al. (2016) [41]	Adults	Adults	Case studies
Gallego Ortega et al. (2016) [42]	Children diagnosed with speech disorders	100 children	Evaluation tests
Gomez et al. (2017) [43]	Adults with psychological problems	1 adult	Case study
Lenz et al. (2015) [44]	Children and adolescents	Children and adolescents	Critical study
Lim et al. (2016) [45]	Adults	Adults	Analytical and descriptive study
Lorusso et al. (2021) [46]	People with dyslexia	People with dyslexia	Questionnaires
Mariño, M.C. et al. (2018) [47]	Adults	1286 patients	Observational, descriptive, cross-sectional study.
Maskati (2021) [48]	Teachers and parents	Teachers and parents	Case studies
Murphy- Ruiz, P.C. et al. (2021) [49]	Adults with language, speech and learning disorders	4632 patients	Retrospective descriptive study
Moreno et al. (2022) [50]	Children with learning difficulties	Children with learning difficulties	Exploratory factor analysis
Navarro-Haro et al. (2016) [51]	Children with concentration problems	Children with concentration problems	Case study
Panadero, C.A. (2019) [52]	Children and adolescents with learning difficulties	Children and adolescents with learning difficulties	Qualitative and interpretative study of a descriptive nature
Pedroli et al. (2017) [53]	Children with dyslexia and ADHD	10 children	Computerised questionnaire
Pérez-Puelles et al. (2022) [54]	Children at high risk of learning difficulties	Children at high risk of learning difficulties	Student <i>t</i> -test
Pestun (2017) [55]	Children with disabilities and dyscalculia	2 children	Case studies
Ralby et al. (2017) [56]	Children with dyslexia		Analytical study
Rodríguez, C. et al. (2018) [57]	Children with neurodevelopmental disorder	Boys	Surveys
Rodríguez-Cano et al. (2022) [58]	Students with learning difficulties	Students with learning difficulties	Qualitative research
Vegas (2021) [59]	Children with language disorders	Children with language disorders	Questionnaires

8. Discussion

Of the 34 studies analyzed in this systematic review, the results show that the contributions of virtual reality and augmented reality in the learning of people with learning difficulties, or in complex healthcare settings, are very beneficial.

We will now comment on some of the research that has been selected in both the health and school environments. The inclusion of health-related research has been determined because of its suitability for factors shared with learning difficulties; thus, we find research whose objective is the training of executive functions, working memory or attention, or the control of impulsivity and hyperactivity.

In the study by Pedroli et al., which was conducted in 2017 with 10 students with dyslexia and ADHD, the results are conclusive. A significant improvement can be seen in the sample of 10 children with dyslexia, after working with virtual reality in different aspects of reading skills [53].

In the article by Navarro-Haro et al., a case study of a 32-year-old female patient with substance use disorder is conducted. She was selected because she had severe memory and attention problems. The patient showed many difficulties in the above areas in both group and individual therapies. The patient underwent, for one month, therapies without virtual reality, in the pre-treatment phase. Once this phase was over, the virtual reality sessions were started. After these sessions, the patient admitted that her concentration had improved. The results of the study indicate that they were significantly reduced, such as suicidal ideation, self-harm. Although this study demonstrates and evidences an improvement in patients who are substance abusers, in only four sessions with virtual reality, it indicates that inattention and impulsivity are fields that are especially sensitive to work with virtual reality [51].

In the review by Freeman et al., also in the health field, different mental health fields are studied in which sessions with virtual reality have been tested. In the case they present about depression, single treatment techniques were performed in small sessions, and it was possible to verify and demonstrate that after working with virtual reality, depression in subjects decreased over time. Tests were also conducted with patients with psychosis and the results indicate that virtual reality is particularly useful for assessing psychosis. In addition, another treatment study has been conducted with 30 patients with persecutory delusions, and the results infer that virtual reality is very effective in terms of reducing delusions as well as reducing stress in final and real-world situations [41].

Pérez-Puelles et al. achieved significant results in the improvement of sustained attention by applying to children at risk of learning difficulties a 12-session training using commercial video games for 30 min in each session.. This research highlights the need for further research on the benefits that video games and emerging technology can bring to learning difficulties [54].

In the psychiatric and healthcare fields, León-Martínez et al. present a study approach for patients with suicidal tendencies and impulsivity control that compares the virtual reality assessment tool “Spheres & Shield Maze Task” and speech analysis to traditional measures. According to the research, VR has evolved into an innovative, appealing, and customizable form of neuropsychological assessment with positive outcomes [60].

According to these authors, training in situations that encourage reflection and inhibit impulsivity could have positive repercussions on this type of suicidal ideation. No results of this interesting study have been found so far.

Perhaps the most significant and relevant study in the educational field is the one conducted in 2021 by Maskati et al. where a group of dyslexic students is evaluated. These students are divided into two different groups, even though they perform the same activity. One of the groups performs the activity through virtual reality, while the other group performs it through traditional learning. The results of the study show that learning coupled with a tool considered as entertainment, yields better results than traditional learning, not to mention the increased motivation of students using this innovative tool [48].

The systematic review was to analyze the usefulness of emerging technologies, such as virtual reality and augmented reality, for students with specific learning difficulties, specifically students with dyslexia and ADHD. Some authors, with their studies, aim to contribute to the inclusion of students with learning difficulties, through different, more attractive, and innovative learning strategies [61,62]. They also believe that both virtual reality and augmented reality would be a great advance for those students who have learning difficulties. Specifically, in students with dyslexia and ADHD, it has been proven that educational re-education therapy with these technologies works positive way, although they must still be complementary to traditional therapies [23].

9. Conclusions

Undoubtedly, technology at the service of education is a very appropriate tandem and this is reflected in the incorporation of emerging technologies such as virtual reality and augmented reality to work with children with learning difficulties generating a safe and controlled environment, close to the interests of young people and adapted to their needs. In addition, these emerging technologies are a resource that improves training processes, given that the sensory inclusion developed by the subject at the time of its use involves it mentally and intellectually in the content to be learned in a positive way [22,63], causing more concentration on the task and greater performance and creativity [64].

Virtual and augmented reality research in education is still in its early stages. The majority of research is focused on health, where significant results have already been obtained [23]. However, these emerging technologies are also being implemented in the educational field, obtaining preliminary results [25,65,66].

Considering the educational field, the reviewed research articles show that the results of the studies are positive with respect to the incorporation of virtual reality and augmented reality in therapies with students at high risk of learning disabilities. The main finding is the improvement in measured values, such as information processing [63].

Therapies with virtual reality and augmented reality, as long as the correct lines of development (phonological awareness, working memory, attention development, perceptual-visual development, perceptual-auditory development, semantic, syntactic and lexical development, and motor development) are worked on, can be very beneficial for the improvement and treatment of learning difficulties [58], having a positive impact on students' reading comprehension and learning permanence [67].

The development of virtual reality in an educational and playful context is also emerging in scientific research, although initiatives in this line are beginning to appear [23,63,68,69], few investigations have been conducted so far [64–66,70]. In particular, virtual reality via mobile devices has been little studied and developed, so there is still a long way to go.

Through the systematic review through the PRISMA 2020 methodology, a synthesis of the state of knowledge has been carried out in relation to the literature on emerging technologies, "Specific Learning Disabilities", specifically dyslexia and "Specific Learning Disorders", specifically attention deficit hyperactivity. All selected articles are based on research in a very new area in the therapeutic approach to learning difficulties, this allows researchers to identify future research priorities, as well as to address questions that otherwise could not be answered by individual studies.

Author Contributions: Conceptualization: M.L.-Á., S.R.-C., V.D.-B. and E.M.-V.; validation: M.L.-Á.; formal analysis: M.L.-Á. and S.R.-C.; investigation: M.L.-Á., S.R.-C., V.D.-B. and E.M.-V.; Resources: S.R.-C. and V.D.-B.; data curation: M.L.-Á. and S.R.-C.; writing—original draft preparation: V.D.-B.; writing—review and editing: S.R.-C., V.D.-B. and E.M.-V.; visualization: M.L.-Á. and E.M.-V.; supervision: S.R.-C. and V.D.-B.; project administration: S.R.-C.; funding acquisition: European Commission. All authors have read and agreed to the published version of the manuscript.

Funding: This work has been co-financed by the Erasmus + program of the European Union through the 2018-1-ES01-KA201-050659 project. That of the European Commission for the preparation of this publication does not imply acceptance of its contents, which is the sole responsibility of the

authors. Therefore, the Commission is not responsible for the use that may be made of the information disclosed here.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee of University of Burgos (IR 13/2020; date of approval: 19 April 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Acknowledgments: We want to thank the collaboration of the research participants as well as the various Dyslexia associations that actively collaborate in the European FORDYSVAR project.

Conflicts of Interest: The authors declare no conflict of interest.

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