A REVIEW OF STUDIES CONCERNING VIRTUAL REALITY AS AN EDUCATIONAL TOOL IN THE TREATMENT OF SPECIFIC LEARNING DISORDERS

LA REALTÀ VIRTUALE COME STRUMENTO EDUCATIVO NEL TRATTAMENTO DEI DISTURBI SPECIFICI DELL'APPRENDIMENTO. UNA REVISIONE DEGLI STUDI

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ABSTRACT

For several years, digital evolution has been assuming an increasingly central role within educational settings as a support in teaching methodologies for Special Needs Students, specifically with Specific Learning Disorders (SLD). The present work aims to provide, through a narrative review of studies, an overview of the effectiveness of using technology as a working tool for SLD students, paving the way for a more innovative development for personalized teaching, including the possibility of using, specifically, virtual reality.

Da diversi anni, l'evoluzione digitale sta assumendo un ruolo sempre più centrale all'interno dei contesti educativi, come supporto nelle metodologie didattiche per alunni BES, ovvero con Bisogni Educativi Speciali, nello specifico con Disturbi Specifici dell'Apprendimento (DSA). Il presente lavoro, dunque, vuole fornire attraverso una revisione narrativa, una visione d'insieme sull'efficacia dell'utilizzo della tecnologia come strumento di lavoro per studenti DSA, che apre la strada ad uno sviluppo più innovativo per la didattica personalizzata, includendo la possibilità di utilizzare, nello specifico, la realtà virtuale.

KEYWORDS
Specific Learning Disorders, Virtual Reality, Personalized Education.

Disturbi Specifici dell'Apprendimento, Realtà Virtuale, Didattica Personalizzata.

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Introduction[1]

The following study aims to conduct a review of the scientific literature regarding the use of Virtual Reality as a working tool for individuals with specific learning disorders.

A common agreement emerges from the scientific community in stating that digital technologies are identified to have significant potential to improve the learning processes of pupils with specific learning disorders by using them as compensatory tools to facilitate and guide the child/adolescent to greater autonomy in learning.

The outcome of the analyzed studies give hope for a future systematic use of technological tools, especially Virtual Reality, being beneficial in different educational aspects: it implies a more realistic approach during treatment and seems to be more motivating and rewarding than traditional training given that subjects are more actively involved in the learning process, in the acquisition of knowledge and understanding of concepts. These processes are followed by a greater sense of satisfaction and fulfillment that positively affect the student's self-esteem, self-image, and confidence in their own resources (Craig et al, 2016; Sakiz et al, 2015).

Following this premise, this study aims to consider the opportunity to take advantage of the context of digital evolution in the educational world. This research also aims to explore the potential of such innovations by creating a link between digital and compensatory tools used to support students with ASD. Therefore, it is intended to investigate the impact of virtual reality in the educational process of the aforementioned subjects.

In this following paper, a screening was carried out starting from the year 2000 to the present, and studies were selected having a group sample consisting of children, adolescents and young adults from universities.

1. Specific Learning Disorders

Specific Learning Disorders, "SLDs" belong to the category of neurodevelopmental disorders with biological origin, whose peculiar symptomatology is characterized

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by the presence of impairments in reading (Dyslexia), written expression (Dysgraphia and Dysorthographia) and calculation (Dyscalculia) in a persistent and non-transitory manner. To assess the presence/absence of the disorder, the Guidelines of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) is referenced, which indicates a prevalence of the disorder of 5-15% among school-age children predominantly in male subjects, and stipulates that such difficulties should occur for a period longer than 6 months, in the presence of average intellectual functioning (IQ>70), and in the absence of neurological, mental and sensory disorders and psychosocial adversity.

Subjects with ASD, have deficits in the area of the prefrontal cortex, where those cognitive abilities primary to the ability to learn reside, such as executive functions (EF) through which the individual can monitor, plan and modify his or her behavior for the achievement of a goal. Specifically, a person with a specific learning disorder, has impairment in the following components of EF: Working Memory, Inhibition and Shifting (Miyake et al, 2000).

Working Memory (Baddeley, 1974) is the ability to retain, transform and reuse information. It has a multi-component structure, of which the following are integral parts: the Phonological Circuit which is responsible for learning new words, and the Visual-Spatial Notebook deputed to integrate spatial (positions and movements) and visual (shapes and colors) information. These abilities are particularly important in the area of reading, as optimal performance in decoding words is the result of an effective memorization process of verbal information, and the ability to integrate visual and spatial information plays a central role in the process of text comprehension and computation.

Through the Inhibition mechanism, on the other hand, the subject is able to inhibit distracting stimuli and voluntarily suppress those responses that may interfere with purposeful behavior.

Shifting, or cognitive flexibility, is the ability that allows one to shift from one mental operation to another by changing his or her behavioral pattern as a result of external feedback.

In addition to having difficulties in learning key school skills, for which the use of compensatory tools to support learners is allowed, pupils also have complications in the relational sphere, such as low self-esteem in themselves and in their own abilities, which are the result of these symptoms, and procede to negatively affect the emotional-behavioral level, becoming a risk factor for dropping out of school. In fact, a pupil's performance in school can be traced to several aspects, such as physical, psychological and emotional well-being.

2. Dyslexia

This following paper focuses on reading impairment, highlighting what are the characteristics of this disability and the consequent targeted interventions.

Dyslexia is a disorder that is characterized by the presence of significant impairments in one or more sub-skills of reading, due to a deficit in the phonological component of language that implies difficulties in accuracy, speed and/or fluency of reading and limited ability to encode and comprehend text.

Regarding the neural architecture of the brains of people with dyslexia, malformation has been observed in the left hemisphere due to cortical ectopias and dysplasias, and in the geniculate nuclei. In addition, structural abnormalities have been observed in the frontal regions and cerebellum. Furthermore during reading tasks, there appears to be decreased activity by the visual word access area, in the ventral pathway which is referred to as the "Word form area", and in the dorsal pathway, that is in the area assigned to the processing of word sounds. Abnormalities are also present in the left inferior frontal gyrus, an area designated for phonological and articulatory processes.

These brain areas go on to affect different aspects of language, such as: phonemic awareness, sound/letter connection, reading fluency, vocabulary and text comprehension.

A distinction can be made between different forms of developmental dyslexia (Cornoldi,1999):

1. Phonological Dyslexia: it involves a difficulty in grapheme-phoneme conversion. The dyslexic subject has difficulty deciphering unfamiliar words.
2. Superficial Dyslexia: involves the lexical-semantic pathway, which enables the reading process to be sped up as it allows the meaning and sound of an already memorized word to be traced by analyzing only the main graphemes that compose it. The person with this difficulty is particularly slow and inaccurate with his or her reading.
3. Profound Dyslexia: affects both pathways, and involves difficulties in speed, decoding and association between meanings. In addition, the subject also makes semantic errors.

As for possible interventions, personalized teaching involves paper-and-pencil or flat-screen computer tasks in order to compensate for difficulties in the processing of automatisms i.e. memorizing names, specific terms, definitions or dates, etc.

Amongst the most effective traditional neuropsychological treatments for reinforcement in reading ability, interventions can be implemented at the lexical and sub-lexical level, carrying out exercises aimed at increasing the ability to memorize letters and syllables automatically, through computer reading training,

or again, automating the reading process, through computer training that consists of reading words that are presented as quickly as possible.
In addition, it is appropriate to specify the usefulness of enhancing some specific components of the cognitive system, such as working and visuospatial memory, which are nodal in reading processes. Furthermore, to train processing speed, which enables automatic performance of cognitive tasks by processing information quickly and efficiently.

3. Virtual Reality

Virtual Reality is intended as a complex environment, the result of a differently immersive, interactive and three-dimensional graphical interface (Melacca, 2016). The subject within the virtual reality, experiences another reality compared to the one in which he/she lives and in which he/she has the opportunity to interact by experiencing behaviors, emotions, sensations, exploiting virtuality as an experiential field suitable for the development of cognitive and social skills functional to the adaptation of the individual to the environment.
With this in mind, the need arises to apply virtual reality into an educational context, creating a more innovative educational offering that paves the way for an inclusive process that is more appreciated by students with SLDs. The factors that characterize virtual reality make it potentially useful and applicable in this context to the extent that it allows multisensory interaction with the visualized space (Christou, 2010). It is well known that humans develop learning processes through the possibility of experiencing the environment with the body using the senses to derive information from the world. Followingly, the purpose of this paper is to show an overview of the scientific evidence in order to document the effectiveness of using virtual reality as a possible resource suitable for enhancing teaching and learning processes by placing the student in an environment in which he or she experiences scenarios and situations rather than imagining them.

4. Methods and Materials

A research was conducted using the Google Scholar and Pubmed databases and including articles published from January 1, 2000 to the present.
For the purpose of the review, the following selections searched in the titles of scientific articles were used:

PICO	**Search term**
Research Sample	Children/Adolescents/Adults affected by SLDs
Intervention	Virutal Reality for treatment

Comparison	Standard Neuropsychological testing
Results	Enhancement of reading and writing in children, adolescents or adults with SLDs

Articles were researched on the databases mentioned above, using the following criteria:
(virtual reality [Title/Abstract] AND Dyslexia [Title/Abstract]).
All articles referring to augmented reality, use of gamefication (excluding VR), other types of disorders in comorbidity with Learning Disorders that were not available in full text or were reviews (either narrative or systematic), notes, letters, or reviews were excluded.
Articles were not excluded based on the size of the sample treated.

5. Results

A total of 47 articles were selected from the before mentioned bibliographic databases. After eliminating the 39 duplicates, 20 articles that had the terms indicated in the exclusion criteria in their titles or abstracts were excluded.
The full texts of the remaining 19 articles were examined in order to further select according to the inclusion/exclusion criteria mentioned above.
Finally, 8 articles were identified for the final review (Fig.1), concerning the use of virtual reality as a rehabilitation tool that improves the effectiveness of learning processes and in particular of reading-writing performance in individuals with specific learning disabilities.
Descriptive data was collected of these articles including: authors' names, year of publication, sample size, study design, mean age, gender and outcomes measured (Tab.1).

Figure 1: Flow Diagram

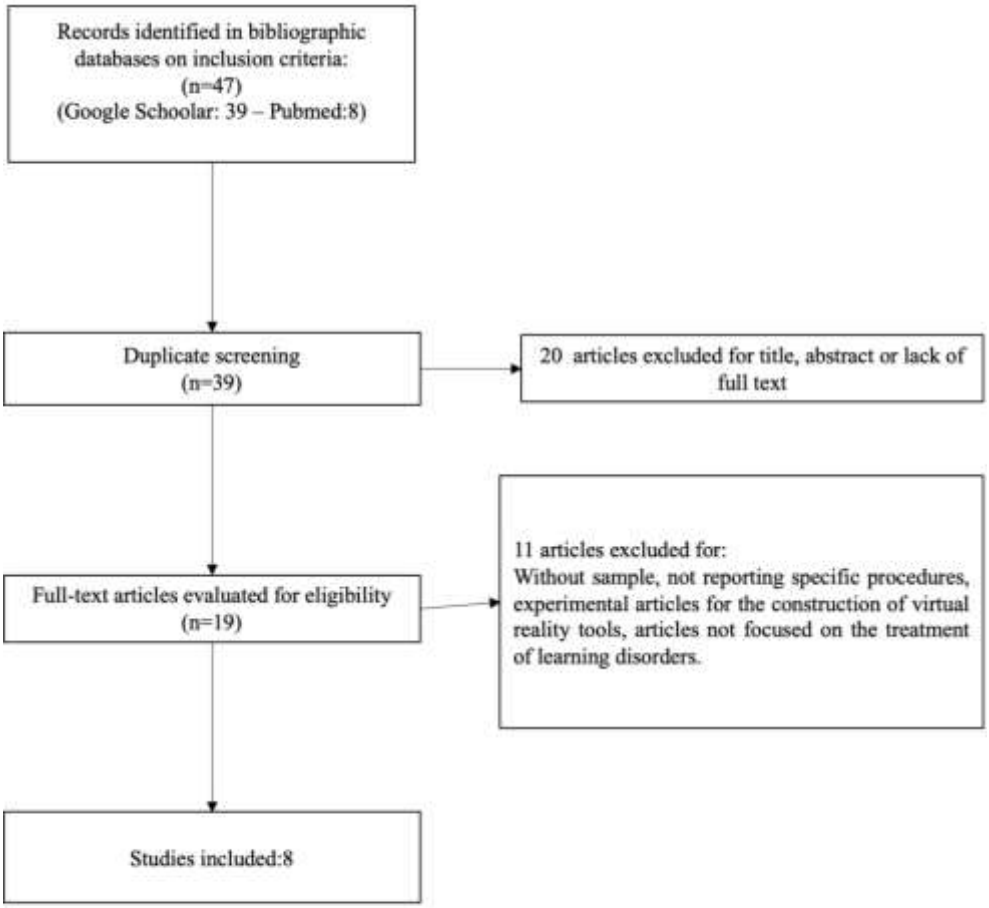


Table 1: SLD treatment systems

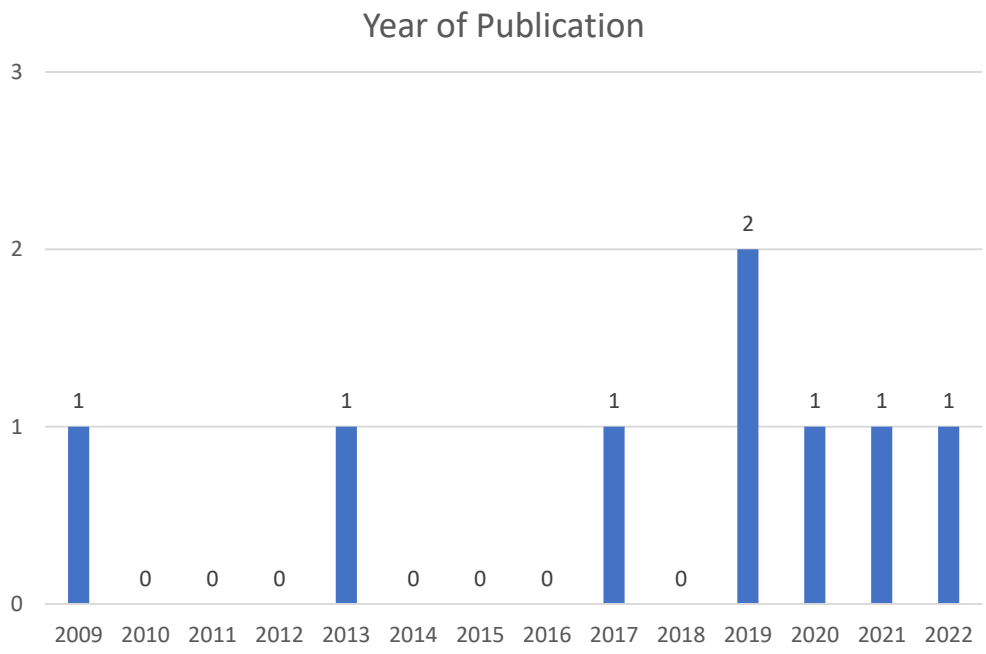
Type	*Study*	*Control Intervention*	*Age average/range*	*Gender - Male (%)*
Trattamento	Attree-2009	VE (3D virtual environment) BAS-2 21 SLD and 21 TD.	13-15 years old	78,6%
	Kalyvioti-2013	VE (VIRDA-MS) 7 DSA and 7 TD.	**Missing**	50%
	Pedroli-2017	VR (Neuro Virtual 3D) ABT, Posner's task and SUS 10 SLD	Avg. age: 10.6 (SD=1.4)	80%
	Buele- 2019	Gamefication VR and SUS. 8 SLD	8-12 years old	62,5%
	Fokides-2019	VE (3D virtual environment) with Avatar and NPC Group 1= 8 SLD VR Group 2 = 8 SLD Video	8-9 years old	50%
	Buele-2020	Gamefication VR and SUS 8 SLD	8-12 years old	**Missing**
	Maskati-2021	VR with avatar Group 1= 5 SLD VR Group 2 = 5 SLD test standard Video	6-7 years old	**Missing**
	Maresca-2022	T0=WISC, DDE VRNT (with VRSS) T1=WISC, DDE 28 SL	Avg. age: 10.3 (SD=2.0)	46,4%

SLD= Specific Learning Disability – TD= Typical Development – VR= Virtual Reality – VE= virtual environment – BAS-2= British Ability Scales – VIRDA-MS= Virtual Reality Dyslexia Assessment-Memory Screening – ABT= Attentional Blink Task – Test di Posner= Measures spatial orientation – NPC= non-playable characters – SUS= System Usability Scale – WISC= Wechsler Intelligence Scale for Children – DDE= Dyslexia and Developmental Dysorthographia Assessment Battery – VRNT= Virtual Reality Neurorehabilitation

Treatment – VRRS= Virtual Reality Rehabilitation System, Khymeia, Padua, Italy – T0= evaluation at baseline – T1= evaluation at the end of the protocol.

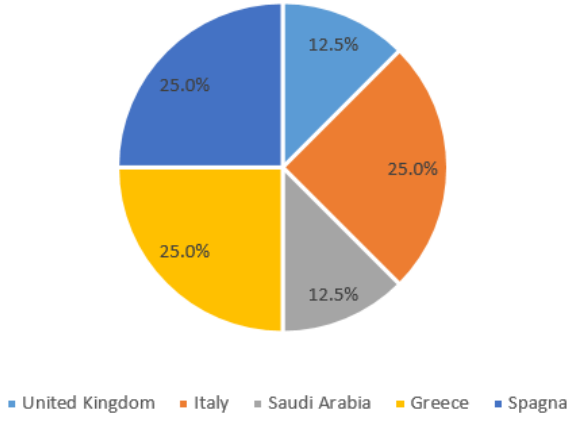
More than 60% of the articles are published after 2017. (Fig. 2)

Figure 2: Number of articles per publishing year.



The articles were evenly published in Spain, Greece and Italy, each with 25%. Meanwhile 13% of the articles were from Saudi Arabia and 12% from the United Kingdom. (Tab. 2).

Table 2: Article frequency per country.



Finally, more than 60% of the articles was realized on a sample of less than 10 people. (Tab.2)

N. Participants	**N.**	**%**
1-10	5	62,5
11-20	1	12,5

21-30	1	12,5
30+	1	12,5

A total of 120 subjects were enrolled in the studies analyzed, almost all of whom were between the ages of 8 and 12 and were predominantly male. Meanwhile in two other studies, the age of the participants were from 6 to 7 years old and from 8 to 9 years old, respectively. Finally in a further study the age of the subjects was not specified, but reference was made to college students, so a sample of adult subjects. Two of the studies did not report information on the gender of the participants.

In almost all of the papers, subjects were included who had average intellectual functioning (70<=QI<=130) of the normal population, who did not have, in comorbidity, other neuropsychiatric disorders (ADHD, etc.), no sensory difficulties such as visual impairment and/or hearing impairment, or, again, no physical difficulties affecting the educational environment.

In most of the works, the assessment of SLD was made through the inclusion and exclusion criteria of DSM-IV or DSM-V. The choice of DSM is mainly related to the year of publication.

Diagnosis was also supported by the use of standardized tests investigating the cognitive area and specifically, with regard to school learning, reading and spelling and visuospatial skills (WISC-IV/ WAIS-R, DDE, NART, WRAT-R2, BAS-2 etc.).

Discussion and Conclusions

Individuals with SLDs, are distinguished by difficulties in academics with reading, writing, and computation; difficulties in text comprehension and maintaining attention may also be noted.

The articles, included in the review study the benefits of using technology and, more specifically, virtual reality as a new opportunity to treat what are some of the deficits present in individuals with Specific Learning Disorders.

In the selected articles, the most widely used tools in VR are aimed at improving learning processes, namely compensating reading skills and enhancing different cognitive domains such as attention, memory, visuospatial orientation and language. In addition, virtual environments are a promising tool for teaching

subjects functional behavioral skills to be implemented in the students' real school environment.

Regarding VR, in all of the analyzed studies, the participant is immersed in a scenario through the use of a head-mounted display (HMD).

Relative to the tools used, a brief overview of the ways in which and for which VR training is applied in dyslexic subjects is subsequently presented.

Pedroli et al. (2017) through the use of "NeuroVirtual 3D" software proposed a VR classroom environment (Virtual Classroom). This scenario reproduced a classroom, where there are student desks, a teacher's desk and a blackboard where visual stimuli were presented and a voice explained the tasks to be performed. Subjects had to perform three different tasks through which the level of alertness, sustained and selective attention, processing speed, and inhibition control were assessed. In the first task, the goal was to detect the presence on the blackboard of a target stimulus among a series of distractor stimuli. In the second, a sequence of letters is presented on the blackboard and respond only to the appearance of the letter "G" followed by the letter "A". Finally, in the last task a story was told to the subject and at the same time four colors were shown on the blackboard, what was required was to identify when one of the four colors was associated with a category within the story being told. Through virtual reality training, the present study aims to enhance the level of attention in order to improve reading ability in dyslexic subjects. In fact, attention is one of the important goals in the treatment of subjects with SLDs, for the improvement of naming speed, decoding ability and phonological awareness (ability to mentally manipulate language sounds).

Virtual Reality training was preceded and followed by three tests in order to assess reading skills and attentional level before and after VR. The results obtained from the following study, show a significant improvement in attention following administration in Virtual Reality. With regard to reading tasks, there were no significant differences other than a significant decrease in reading time of long words at low frequency, which goes to support the validity of the proposed approach.

Another study, of which the purpose purpose is to increase the cognitive skills underlying reading in children with dyslexia is the one proposed by Maresca (2022). This study proposes an intervention on dyslexic children based on the use of a VRNT "Rehabilitation System in Virtual Reality," which allows simulating real-life scenarios, recreating real events and three-dimensional objectsthrough the computer, with the aim of improving the cognitive skills of the subjects. With respect to the aftermentioned aspect, various activities are proposed with more than fifty repetitive virtual exercises, with increasing difficulty depending on the time of execution and the type of exercise to be performed, in order to enhance

cognitive domains such as memory, attention, language, spatial orientation and executive functions. Through this tool, there seems to appear better performance cognition, which is closely related to high motivation and active exploration on the part of the subject involved in VR training that result in the performance of longer workouts and therefore greater success in performance quality. On this account, significant improvement was found in subjects who performed VR training, compared to the control group, both in reading tests such as the DDE and in scores obtained in the WISC-IV cognitive domains test.

Thus, one can consider the use of VR as having significant potential for maintaining and improving language skills and cognitive performance in subjects with dyslexia.

Regarding visuospatial orientation and spatial memory of adolescents with dyslexia, the study by Attree et al. (2009) proposes activities in a virtual environment (Bungalow) consisting of four interconnected rooms: a bedroom, music room, living room and kitchen, within which household objects were placed. Participating subjects were required to memorize the different objects that were presented to them and to locate a particular target object within one of the aforementioned rooms. Following this, subjects were asked to note down the number of rooms present and to perform a spatial layout memory task, that is, to construct a floor plan of the virtual environment on the whiteboard using geometric shapes: rectangles, squares, circles, etc. Another task required participants to remember the essential design features of the various rooms that made up the Bungalow. The objective of the mentioned study was to measure spatial recognition memory since both children and adults rarely pay attention to the various details of different places. The results obtained seem encouraging in that they show that the performance achieved by dyslexic subjects is significantly higher than that of typically developing subjects. These results support research that considers the role of visuospatial skills to be valid, both as predictive tools for the identification of school skills in pupils with learning difficulties, and on the educational level by using them as possible learning tools for dyslexic subjects who have difficulty learning by other means.

In Kalyvioti's (2013) study, virtual reality was used to identify memory difficulties and skills in college students with dyslexia, and consequently through interaction with VR recognize possible compensatory memory strategies. Three tasks were designed in VR that gradually increase in difficulty level and are divided into two subtests one with the presence of objects with semantic content and the other with stimuli without semantic content, to investigate three memory systems:

- Short-term memory task (Forward digit span): students were asked to memorize the correct sequence of visual stimuli presented. Next, participants had to name the order of the presented stimuli.

- Working memory task (Backwards digit span): participants were asked to memorize the reverse order of the visual stimuli presented to them.

In these first two tasks, the virtual environment consisted of a two-story house where various objects were distributed.

- Long-term memory task (Visual Stimuli Synthesis): in this case, the virtual scenario within which the tasks were carried out was an art gallery. Participants were asked to recognize a sequence of semantic and non-semantic images that made up an image that was not shown to them in its entirety, but divided into two halves. The goal was to be able to identify which painting it was from the individual images presented.

There were no significant differences in any of the three memory tasks between the sample of dyslexic students and the control group, and this may be controversial as a result with respect to what the literature states about the low performance of dyslexics in memory tasks. However, we would like to point out the consistency of the results obtained from Kalyvioti's (2013) study with that of McLouhglin et al (1994), which highlight the possibility for dyslexic adults to develop compensatory memory strategies. In fact, it has been observed through VR training how all participants (case and control) implement common compensatory strategies designed to improve their memory skills.

Buele (2019-2020), in both selected studies, proposes training in a virtual environment through video games designed to enrich and compensate language skills in individuals with SLDs. The aforementioned video games allow participants, to experience a multisensory experience through the playback of visual and auditory messages that make VR a more engaging and interactive system, so as to facilitate learning in subjects with deficits related to language skills. In fact, subjects are asked to listen to sounds, point to syllables, complete words, etc. and as they reach higher levels of difficulty, they are rewarded through virtual rewards that seem to be able to motivate children more in achieving their goals.

Maskati (2021) proposes a study that also uses virtual reality with the aim of teaching dyslexic elementary school students the letters of the alphabet in a more engaging and comfortable way by creating a link between education and entertainment in order to enhance the learning process. The proposed system, is a mobile application built for educational purposes, equipped with the VR viewer function, and an avatar that pronounces the letters that the subjects want to learn and guides them to use the application as accurately as possible by having the subjects track through the controller the letter presented in different situations. The results obtained as a result of this study, revealed that the application successfully supported the learning of both typically developing students and students with dyslexia.

In conclusion, Fokides (2019) proposed activities in a virtual environment representing an imaginary school complex with classrooms and courtyard, various details that made the environment as realistic as possible such as the bell ringing, lockers opening, common school noises, etc., and there was the presence of "Non-Playable Characters" (NPCs) i.e., characters that could not be played as, represented by students or teachers. Students participating in VR training through their avatar explored the environment independently. The author 's proposed goal was to teach through immersion in the virtual environment to students with developmental dyslexia who exhibited problem behaviors, behavioral skills that were functional in the school environment. The proposed scenarios, involved the presence of difficult behaviors and situations structured under different conditions: during class, recess, and school events. The following study showed that through the use of VR, there is a significant increase in desired behaviors within the school environment.

The performed overview allowed to observe that the use of virtual reality engages subjects to a greater extent, motivating them to learn. Although, not in all papers do the results show statistically significant differences; the VR scenario seems to be a resource with greater validity and effectiveness in enhancing cognitive and language skills in children/adolescents with SLDs.

Almost all of the selected studies, had the limitation of a small sample size, so in future research, it would be appropriate to replicate the various studies on a larger sample, so as to be able to extend the results obtained to the entire population of SLDs, also taking into account the presence of possible disorders in comorbidity in subjects with this deficit, and possible complications in the group of subjects with typical development, in order to avoid misclassification errors.

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