

Development areas for intervention in dyslexia: a virtual reality proposal

Áreas de desarrollo para intervención en dislexia: una propuesta de realidad virtual

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Abstract

The research presented is part of the European Erasmus + FORDYSVAR project, whose main objective is to contribute to the educational inclusion of students with dyslexia, between the ages of 10 and 16, through the use of technology, specifically virtual reality (VR) to improve access, participation, and learning achievement for students with this literacy disorder. It is a qualitative and interpretive research with a descriptive nature. To determine which are the developmental areas for intervention through VR, semi-structural interviews were conducted with stakeholders (experts in dyslexia, families and children with dyslexia). The results obtained, derived from the content analysis of the interviews carried out and submitted to review by experts, make it possible to determine seven development areas to take into account in the design of the activities included in the virtual reality software developed in the FORDYSVAR project.

The work carried out can contribute to the advancement in the inclusion, treatment and rehabilitation of people with dyslexia through technology and specifically through VR, enabling an immersive and attractive environment to develop the visuospatial skills of students with dyslexia.

Keywords: Specific learning disorder; dyslexia; virtual reality; educational technology; special need students

Resumen

La investigación presentada se enmarca dentro del proyecto Europeo Erasmus+ FORDYSVAR, cuyo objetivo principal es contribuir a la inclusión educativa de los estudiantes con dislexia, en edades comprendidas entre los 10 y los 16 años, mediante el uso de la tecnología, concretamente la realidad virtual (RV) para mejorar el acceso, la participación y los logros de aprendizaje de los estudiantes con este trastorno de lectoescritura. Se trata de una investigación de corte cualitativo e interpretativo con un carácter descriptivo. Para determinar cuáles son las áreas de desarrollo para la intervención a través de RV, se realizaron entrevistas semiestructuradas a grupos de interés (expertos en dislexia, familias y niños con dislexia). Los resultados obtenidos, derivados del análisis de contenido de las entrevistas realizadas y sometido a revisión por expertos, permiten determinar siete áreas de desarrollo a tener en cuenta en el diseño de las actividades incluidas en el software de realidad virtual desarrollado en el proyecto FORDYSVAR. El trabajo realizado puede contribuir al avance en la inclusión, tratamiento y rehabilitación de las personas con dislexia a través de la tecnología y concretamente mediante RV, posibilitando un entorno inmersivo y atractivo para desarrollar las habilidades visoespaciales de los estudiantes con dislexia.

Palabras clave: Trastorno específico del aprendizaje; dislexia; realidad Virtual; tecnología educativa; estudiantes con necesidades especiales

Introduction

In this article, we will deal with dyslexia as a specific learning disorder that has a neurobiological origin and encompasses a difficulty in the accurate and fluent recognition of words, resulting in deficiencies in the phonological component of language, affecting the sphere of reading and - in some cases - writing too (National Institute of Neurological Disorder and Stroke, 2016).

Specifically, research conducted in the context of the FORDYSVAR European project (2020) “Fostering inclusive learning for children with dyslexia in Europe by providing easy-to-use virtual and/or augmented reality tools and guidelines” is presented. The purpose thereof aims at determining the areas of development for intervention for students with dyslexia, specifically through the design and creation of a virtual reality (VR) software to promote learning for students with this disorder that impacts reading and writing.

The research question that articulates this scientific contribution is aimed at identifying which are the main areas of treatment and educational intervention that should be present in the application of virtual reality to work with children with dyslexia.

Dyslexia: A Conceptual Approach

The etymological origin of the word dyslexia comes from the Greek *dys* - meaning difficulty - and *lexia* - meaning reading, referring to the difficulty in reading, a term coined in the late 1880s (UNESCO, 2020).

According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-V), dyslexia falls within the subcategory of neurodevelopmental disorders called “Specific Learning Disorder” and

refers to a pattern of learning difficulties characterised by problems with accurate or fluent word recognition, misspelling and poor spelling skills (American Psychiatric Association, 2014).

Therefore, dyslexia can be defined as a specific disorder that affects learning to read and write and is persistent and specific in nature. Its origin is derived from a neurodevelopmental disorder and it is characterised by the difficulties that the individual has in recognising certain words fluently and accurately, as well as the ability to decode and spell due to a deficit in the phonological component of language and affecting the reading sphere (Benítez-Burraco, 2010; Cidrim & Madeiro, 2017; National Institute of Neurological Disorder and Stroke, 2016).

People with dyslexia have a deficit in phonological awareness, verbal memory and verbal processing speed that does not correspond to the developmental stage in which the person is (Protopapas, 2019) and is prolonged over time, regardless of the individual's good cognitive abilities and high performance (Cuetos et al., 2019).

They also have difficulties in differentiating sounds and words, memorising, transforming individual sounds into words, as well as remembering letters and their sound equivalents (Dymora & Niemiec, 2019). This is because there is an impairment that affects the functionality of reading behaviour, which makes it impossible for the individual to extract written information correctly and efficiently. It thus impacts his academic, personal and social adaptation (Cuetos & Domínguez, 2012).

Contributions to dyslexia from the field of technology

Nowadays, the incorporation of information and communication technologies (ICTs), educational technology (ET) design and software development in the educational field contributes to school intervention. This offers playful and effective environments for the treatment of different disorders in children and adolescents, with the advantage of providing safe and controlled environments, generating motivation, providing high level of interactivity, immediate feedback and contributing to the improvement of visual processing skills and short-term memory (Phipps et al., 2002; Kalyvioty & Mikropoulos, 2014).

In this vein, research has been conducted using technological tools to facilitate intervention in specific learning disorders in reading and writing. For example, Cidrim et al., (2018) develop a multisensory application for mobile phones, which enable children with dyslexia to cope with mirror writing.

Jiménez and Díez (2018) validated some elements of Minecraft to work on reading problems, and concluded that the visual, spatial, audio and kinaesthetic resources contained in this video game allowed the user to experience the input of information through a series of modes of access, favouring the learning of reading in a multisensory way and that it can be very beneficial for people with special educational needs (SENs) in general and specifically for people with dyslexia.

Along the lines of gamification, Dymora and Niemiec's (2019) research focuses on working on dysorthography and spelling errors in people with dyslexia through a game available for smartphones and tablets.

In the same line of work, the video game called *Trasdilexia* (Jiménez-González, 2006) has been designed to improve reading processes in children and young people with dyslexia. This application is aimed at improving the processes of speech perception, phonological awareness, orthographic processing, syntactic knowledge and reading comprehension, through activities set in different scenarios where the real and fictitious worlds are mixed.

More specifically, virtual reality is an emerging technology in recent decades, but in the last fifteen years it has become a powerful educational element and a tool for assessment and intervention in the school environment (Aznar-Díaz et al., 2018). This is possible because this technology allows for the generation of dynamic and controllable 3D environments, stimuli control, documentation and quantification of behaviour, characteristics that make it unique (Rizzo et al., 2013; Xi & Hamari, 2021).

Mikropoulos and Strouboulis (2004) state that “virtual reality is a combination of high-quality computing, computer interfaces, graphics, sensor technology and networks that allows the user to immerse, interact and experience in real time a three-dimensional (3D) artificial environment representing realistic or other situations” (p. 583).

The versatility offered by this VR technology makes it adaptable to different contexts, one of them being learning disabilities.

Within the technological field, virtual reality can make important contributions to the treatment of dyslexia, as it offers 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 learner (Rodríguez-Cano et al., 2021). It also provides immediate feedback and can have high levels of interactivity (Kalyvioty & Mikropoulos, 2013) along with the possibility of offering a multisensory approach (Broadhead et al., 2018), and is considered one of the most promising avenues of treatment in the field of dyslexia (Birsh, 2011).

Method

This paper focuses on the field of learning difficulties, specifically on dyslexia, the most frequent difficulty in today’s education (De la Peña, 2016). Therefore, this research aims at contributing to the educational inclusion of students with dyslexia through the use of technology, specifically through virtual reality.

This is a qualitative and interpretative research with a descriptive character. User-centred design (UCD) has been applied in this study as a model for involving participants in the phases through which a product is developed, achieving greater user satisfaction and productivity and an easier understanding of the system on their part (Maguire et al., 2006). This way, the application that is designed and developed will make sense to the end user, who takes on the role of co-designer (Rubio et al., 2014).

Following ISO 9241-210 (2010), UCD is characterised as design-based on an explicit understanding of user needs, tasks and environments. It was carried out and evaluated by a multidisciplinary team with the participation of users and using an iterative process covering the whole user experience. To this end, three essential phases are defined:

- 1) Firstly, collecting and specifying system requirements within the context of use and by users.
- 2) Secondly, the design phase in which different prototypes will be tested.
- 3) Thirdly, the evaluation of the system by the users themselves.

Objectives

The overall objective of the European Erasmus+ FORDYSVAR project is to design a virtual reality application that contributes to learning of students with dyslexia, using user-centred design (UCD) as a methodology.

To meet this overall objective of the project, this contribution aims at identifying and defining the development areas for intervention that need to be addressed in the VR application.

Procedure

In order to define the work areas to be worked on in the virtual reality application based on the user-centred design methodology, two different phases have been proposed with a methodology in each phase.

The first one is based on qualitative research using data collection without numerical measurement to discover or refine the research questions (Hernández et al., 2010). The second phase consists of the development of the proposal with the areas of intervention the application should have.

Phase 1 focused on the construction of the interview as a data collection instrument, as well as the analysis of the content obtained. Phase 2 established and developed the dyslexia intervention guidelines used for the design of the virtual reality game.

For phase 1, a literature review of the scientific literature published in the last 10 years was carried out in the Scopus database, using the following descriptors: dyslexia and treatment approaches. Of the 114 papers retrieved, the 21 results that fell into the social science category were selected as they were research developed in the educational and pedagogical field.

In the process of constructing the interview, the questions were made by consensus of the members of the research team. As they were semi-structured interviews, it was possible to integrate information that arose during the interviews in the different groups that were the object of the research.

The content of the interviews was validated out in each country, using the expert judgement technique. This way, the reliability of the research was verified, through the informed opinion of people with a track record in the subject, recognised by others as qualified experts, and who can give evidence, judgements and assessments (Escobar-Pérez & Cuervo-Martínez, 2008).

The interview was first designed in English and then translated into the language of each country for its administration. Each country administered the interview to selected project

stakeholders: teachers and/or dyslexia intervention specialists, students and family members (Rodríguez-Cano et al., 2020a).

In phase 2, after the interviews were conducted by the partner countries, they were transcribed and translated into English for a joint content analysis. Following the analysis of the information gathered from the stakeholder interviews, ten categories were initially extracted and later reduced to seven categories in which learners with dyslexia have more difficulties and therefore need more specific work.

Participants

In both phases of the study, an incidental non-probability sampling type has been used, in which the researcher directly selects the sample because it is representative and easily accessible (Sabariego, 2004). This type of sampling is one of the most common in educational research (McMillan & Schumacher, 2001).

In phase 1, participants were dyslexia intervention specialists, teachers, students and their families. In this respect, the participant sample was selected according to inclusion criteria for each target group:

- Specialists in dyslexia intervention: duly qualified professionals of pedagogy, psychology or speech therapy.
- Families of students with dyslexia: parents and/or legal guardians of children diagnosed with dyslexia.
- Students: children aged between 10 and 16 diagnosed with dyslexia.
- Teachers of students with dyslexia: teachers who currently teaching students diagnosed with dyslexia in their classrooms.

The target groups of the study who participated in the open-ended interviews to find out the most effective interventions in the field of dyslexia are shown in table 1.

Table 1.
Stakeholders by country

	Spain	Italy	Romania	Total
Dyslexia intervention specialists	3	3	3	9
Families of students with dyslexia	3	3	3	9
Students	3	3	3	9
Teachers of students with dyslexia	3			3
Total	12	9	9	30

This sample is made up of a total of 30 participants, 9 from each partner country (Italy and Romania) and 12 from Spain, as 3 teachers were interviewed in addition to experts. In no case did participants receive compensation for participating in the study. The motivation for participating in the project lies in the contribution to scientific progress in the field of the study of specific learning disorders and, specifically, dyslexia of the interest groups that make up the selected sample of participants.

On the other hand, the lines of development and intervention on which the activities were developed (phase 2) were reviewed by a group of Spanish experts, whose sample is made up of a total of 5 professionals including 3 specialists in dyslexia (speech therapist, therapeutic pedagogue and psychologist specialising in language) and 2 external professionals who are experts in virtual reality. This technique was selected because it is a widely used strategy for the design and evaluation of teaching materials in the field of educational research (Área & Guarro, 2012; Cabero & Barroso, 2013), because we considered that experts could provide us with reliable assessments of the system, while offering their recommendations and suggestions based on the skill results (McMillan & Schumacher, 2001).

Instruments

Information was collected through interviews with the stakeholders (teachers and/or dyslexia intervention specialists, families and students with dyslexia). According to Corbetta (2003), interviews as an evaluation method, because of their flexible nature, are considered to provide more focused and comprehensive information than questionnaires.

The interviews have a semi-structured design, with relevant but open-ended questions, allowing the interviewee to give a freer, deeper and fuller response (Sabariago et al., 2004). The script of the interviews and their content was discussed and agreed upon by the other project partners until a final version in English was obtainedⁱ.

The interviews were then translated into the languages of the participating European consortium (Spanish, Italian and Romanian). The interviews were administered by each country in their own language and upon completion thereof they were then transcribed and translated into English for joint content analysis. As for the collection of interview data, it ended when the participants had no further input.

Data analysis

In order to conduct the analysis of the data obtained in the interviews, content analysis was conducted as a qualitative research technique that aims at converting symbolic behavioural phenomena into scientific data through the objective, systematic and quantitative description of the material content of the communication or any other manifestation of behaviour to facilitate an objective view of the event (Martín, 2015).

According to Arbeláez and Onrubia (2014), thematic content analysis considers the presence of terms or concepts independently of the relationships between them, the most commonly used techniques being frequency lists; thematic identification and classification; and word search in context. Within these techniques, terms or concepts are selected and sometimes defined before starting to specify the units of analysis.

The criteria used to analyse the textual data from the different interviews were thematic, following the inductive method and trying to identify the central axes or main thematic categories in the content.

Results

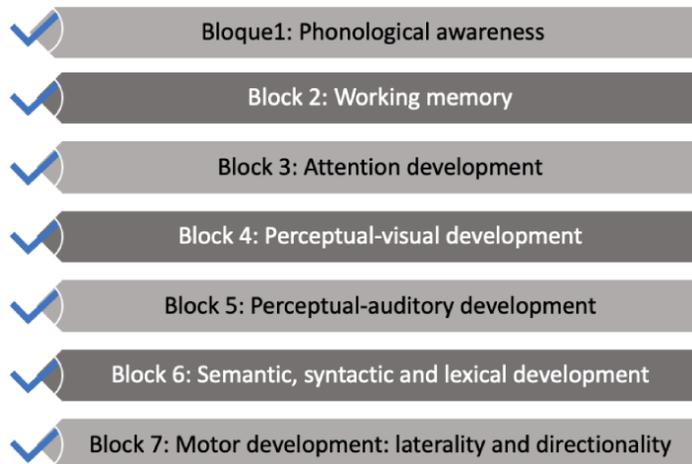
In view the various areas in which people with dyslexia have difficulties (Fletcher et al., 2019) and following the content analysis of the stakeholder interviews, ten categories were initially extracted in which students with dyslexia have more difficulties and therefore require more specific work (Rodríguez-Cano et al., 2020b): lexical development, phonological awareness, short-term memory, visual-perceptual development, auditory-perceptual development, semantic development, motor development balance, reading anxiety reduction, attention and reading fluency.

This analysis was submitted to expert judgement by doctors of education, dyslexia specialists and external professionals with expertise in virtual reality who expressed their opinion and made different proposals for the development of the software within the axes of intervention analysed.

Finally, after peer review and consensus with the partners, seven areas of development were identified as the basis for the content blocks on the basis of which the activities that make up the virtual reality application have been designed (figure 1).

Figure 1.

Content blocks and areas of development



Block 1: Phonological awareness

Phonological awareness is the awareness through which we take over our own language and allows us to consciously distinguish letter-sound sequences and correspondences (Cuetos et al., 2012), i.e., the ability to recognise phonemes.

Rosseli et al. (2010) argue that phonological awareness predicts the progress of reading skills within a metalinguistic process, the relationship between phonological awareness and literacy being bidirectional since phonological awareness favours the acquisition of literacy and its teaching develops this awareness.

Therefore, reading poses a particular challenge because of existing evidence that students with dyslexia have particular difficulty decoding phonemes (Abdul-Hamid et al., 2015; McArthur et al., 2015).

Activities were developed on grapheme-phoneme relationships, syllable recognition (syllabic awareness), reading words and pseudo-words (lexical awareness) and phonemic awareness in order to work on phonological awareness. Phonological awareness is used transversally in the methodology.

Block 2: Working memory

To read a paragraph correctly, we need to retain the beginning of a written sentence in order to understand the end. A long and complex sentence will be much more difficult to understand than a short and simple one (Martín-Lobo, 2003). Working memory is thus related to correct reading comprehension, which has also been called reading memory.

Working or working memory is currently conceived as the basic capacity needed to perform complex cognitive activities (reasoning, comprehension, learning), and it is essential for analysing, processing, monitoring and retaining information in the performance of these activities (Bonfill et al., 2015).

García-Madruga et al., (2007) state that it is studied as a potential factor and determinant of individual differences in the main cognitive skills.

Short-term memorisation activities have been planned through activities involving the selection and identification of letters and symbols on a visual level (association of images with quantities, association of image and number, etc.), identification of sounds and repetition of series of letters, numbers or words.

They also work on instructions and characteristics that they will have to remember or memorise in order to advance in the game.

Block 3: Attention development

Attention mediates sustained memory processes for the execution of certain activities in conscious perception, in the allocation of cognitive resources, and in the interaction with long-term memory (Gordillo et al., 2014).

It may also be linked to a deficit in concentration, which is sometimes confused with ADHD, although the origin of the inattention is different (Regan & Woods, 2000).

Attention and selective attention are worked on in a playful way in practically all the activities of the application. These will be aimed at identifying differences; identifying the consonant sound repeated in all the words in a series; searching for matching objects in groups; narrated story giving clues (being able to retrieve information); providing auditory support of texts and retrieval of information.

Blocks 4 & 5: Perceptual-visual and auditory perceptual development

Following the contributions of Franceschini et al., (2012), visuospatial attention deficits may be linked to dyslexia. In a three-year longitudinal study, these authors found that individuals with reading difficulties already reported deficits in these aspects when they were pre-readers; confirming the validity of visual discrimination and visuospatial attention not only as predictors of dyslexia but also as a possibility for treatment.

According to these authors, struggling readers also showed impaired auditory-phonological processing in syllable discrimination activities when they were pre-readers. Both avenues of research are currently open.

At a perceptual-visual level, activities will be carried out to recognise words within a text: reading incomplete words, activities to find the differences; continuing a visual series from a model, etc. For perceptual-auditory development, we will work on exercises to identify sounds in words; first and last sound of a word; words that begin with the same sound, musical sounds have also been introduced that must be associated with an instrument, the characters in the game have different types of voice with wide registers to work on this block of content, etc.

Block 6: Semantic, syntactic and lexical development

Reading is a seemingly quick activity, requiring automatisms and a series of mental operations to reach the meaning and pronunciation of written words. It is also linked to three processes of interaction between the reader and the text: first, to the phonological in the transduction of grapheme to phoneme, second, to the identification of the word in relation to its respective meaning and, finally, to the comprehension of the meaning of the text (Martín-Lobo, 2003).

Therefore, reading involves transforming graphic signs that appear on paper or a screen into sounds -in the case of reading aloud- or into meanings -in the case of silent or comprehensive reading (Cuetos & Domínguez, 2012).

Within semantic development, some of the activities will focus on word and sentence comprehension, reading instructions and understanding plot and narrative.

Lexical development will be worked on through activities with pseudo-words. Working through the pseudoword technique is endorsed among dyslexia specialists as a useful method of work and treatment (Aguado et al., 2018).

Block 7: Motor development: laterality and directionality

Based on the results of their research, Oliveira and Capellini (2013) concluded that students with dyslexia show impaired motor development, with lower skills in global motor function, balance, spatial organisation and temporal organisation.

On the other hand, Ruíz-Pérez et al. (2016) conducted an analysis of the different research on motor development and language development, proposing a more exhaustive analysis of this

relationship and the joint intervention of both areas for the development of language problems and motor problems, as they find numerous evidences of a parallel and interrelated chronology between both developments.

The activities to work on motor development will be related to visual-motor coordination (pointing and shooting with the pointer, moving pieces by dragging with the finger, moving figures and selecting the right one), balance (avoiding obstacles) and spatial orientation, by working on location on maps or GPS.

Discussion and conclusions

This methodology is currently being implemented in a virtual reality video game, but due to its flexibility it can have different applications in working with children with dyslexia or other difficulties that encompass the contents developed in our research.

The results of the research developed respond to one of the objectives set in the context of the European Erasmus+ FORDYSVAR project in relation to the design of a virtual reality application that can contribute to learning among students with dyslexia. It has been developed taking into account the needs of end-users as well as the vision of professionals.

In order to meet this objective, open interviews related to the field of dyslexia were conducted with stakeholders (teachers and/or specialists in dyslexia intervention, students and family members), extracting different areas of intervention and structure of the video game. Data collection and subsequent peer review made it possible to determine the areas of development for intervention in specific learning disorders in particular in students with dyslexia through the use of virtual reality.

Seven lines of activity development (phonological awareness; working memory; attention development; visual-perceptual development; auditory-perceptual development; semantic, syntactic and lexical development; motor development: laterality and directionality) have been extracted, taking into account the various areas in which people with dyslexia have difficulties, as well as the analysis of the content of the interviews conducted with the target groups. All of this has been reviewed by dyslexia experts and agreed by the project partners.

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 (Attree et al., 2009; Broadhead et al., 2018), few investigations have been carried out so far. In particular, immersive virtual reality based on the use of mobile digital devices is still in its infancy and there is still a long way to go in its application for it to be more widely implemented (Aznar-Díaz et al., 2018).

Therefore, in order to lay a solid foundation for the treatment and rehabilitation of people with dyslexia through virtual reality (VR), more scientific studies are required to support the effectiveness of these interventions (Ausín et al., 2019).

The research carried out presents a novel proposal for the therapeutic approach to dyslexia through the use of technology, specifically virtual reality. As for the initial design of our project, it should be noted that a review of the state of the art revealed a lack of research on the

subject, hence the relevance of the work presented, as it represents a step forward in this area of knowledge. Other proposals also focus on the use of technology as a resource to work on the difficulties derived from dyslexia, however, what differentiates our work from others is the motivational nature of the software designed as it has been created by the end users (children with dyslexia) and also allows the user to immerse themselves in another reality as it is an immersive virtual reality application in which the player not only sees a different reality through the VR viewer but can interact with it through the use of specific controllers.

After the work carried out so far, we can conclude that in order to offer an adequate educational response to students with dyslexia, it is necessary the collaboration of the school, family and social context, agents that must be part of the decision-making process, with the aim of achieving changes that make it possible to improve the situation. On the other hand, technology can show us another way of treatment by offering a playful, safe, controlled and motivating environment for students with dyslexia.

We believe that the work carried out within the European Erasmus+ FORDYSVAR project can contribute to the advancement of inclusion, treatment and rehabilitation of people with dyslexia through technology and specifically through virtual reality, enabling an immersive and attractive environment to develop the visuospatial skills of students with dyslexia. However, we believe further research is necessary in this field in order to give scientific support to the use of virtual reality in the diagnosis and treatment of dyslexia.

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Notes

- i The data collection instruments can be found at https://bit.ly/Anexos_B-B-2701 to facilitate replication of other studies.