# A virtual reality serious game for children with dyslexia: DixGame

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**Abstract.** Children with reading and writing difficulties, such as dyslexia, have been directly affected by the Covid-19 situation because they could not have the teacher's face-to-face support. Consequently, new devices and technological applications are being used in educational contexts to improve the interest of learning. This paper presents the design of a Virtual Reality Serious Game called DixGame. This game is a pedagogical tool specifically oriented to children between 8 and 12 years old with dyslexia. Two immersive mini-games are included in this game: a Whack-a-mole and a Memory, which try to improve different skills keeping the children focused on tasks. Whack-a-mole aims to work on the attention and visual and reading agility by recognizing correct letters and words. Memory aims to improve memory and attention ability by pairing letter-cards. The mini-game structure permits to incorporate new levels or games and the progressive increment of difficulty allows the autonomous treatment.

**Keywords:** virtual reality, serious game, dyslexia, education, children

## 1 Introduction

Children with Specific learning difficulties (SpLDs) learn concepts more slowly for their age or educational level. Nevertheless, SpLDs are not related to the intelligence but to the rate of learning. People with this type of difficulties have oral and writing language problems and reading comprehension deficits. Some examples of SpLDs are dyslexia, dysgraphia, or dyscalculia. Special education is the most effective therapy for SpLDs, and it must be complementary to regular education for children with these

conditions. Special education is provided by teachers specialized in the subject and can be done in a group or individually [1].

In recent years, the new devices and technology applications have become a necessity in the treatment of learning disorders. Crises such as COVID-19 have delayed children and adolescents with reading and writing difficulties. This situation has created a considerable disadvantage, especially to people who suffer from some learning disorder [2]. Consequently, many teachers brought some applications and resources within reach to their students to intended to alleviate this delay. These applications would help them not to miss the pace of classes, even if they were at home. Currently, there are many applications for the treatment of learning disorders for the typical devices like tablets. Nevertheless, this type of technology is not immersive, and the lack of immersion can cause children to neglect interest in the application [3]. Children with reading and writing difficulties may be unattracted to educational content, therefore, immersion can support them because it is a positive component for emotional support [4].

This article will explain the design of a VR videogame called DixGame for the treatment of dyslexia in children between 8 and 12 years old. This game has educational content integrated with funny game mechanics for children to learn without realizing it. DixGame contains two games intended to deal with different reading and writing difficulties: Whack-a-mole and Memory.

The remaining sections of this paper will be organized as follows: in Section 2, the development of the immersive VR serious game for dyslexia treatment will be described. The conclusions and future lines of work will be presented in Section 3.

## 2 Related work

Dyslexia is the most SpLDs known. Many dyslexic readers experience visual-perceptual problems, such as shifting and reversal of letters in a word. This causes words to appear to be moving, distorted, crowded, or overlapping [5, 6]. Dyslexic people, therefore, show more diffuse attention and have difficulties in tasks that require focused attention and visual search [7]. As a result, this condition entails a significant educational and occupational disadvantage throughout their lives [8].

Serious Games (SG), also known as games for learning, are activities designed to entertain users in an environment where they can also learn, educate, and train themselves in diverse areas and tasks. The main goals of a SG should be interaction, user engagement, immersion, and photorealism [9]. SG present a student-centered approach to education, unlike traditional teaching environments where the teacher controls the learning. This feeling facilitates active and critical learning [10]. Thus, to design an effective SG, it is necessary to incorporate gamified elements. Gamification can be defined as the use of game design elements in non-game contexts [11]. This technique looks for increasing usability and satisfaction and promoting more pleasant experiences to drive behaviours [12].

Nowadays, the way of learning of young people is changing and being adapted to the current technologies [13]. The use of these technologies, such as Virtual Reality

(VR), aims to innovate and improve the educational field. This is intended to make the learning process flexible, collaborative, and individualized [14]. Numerous studies have tried to compare learning in VR and traditional learning with encouraging results [15, 16]. VR improves learning, and participants acquire greater commitment and more positive emotions. And a positive state of mind can also have favorable effects on learning.

VR offers two very important components for improving the rate of learning: presence and immersion [17]. Presence represents the feeling of "being there"; that is to say, the feeling of existing in the virtual environment [18]. Immersion is defined as the technological fidelity of VR that hardware and software can evoke [19]. Most people prefer and active learning than a passive one and 3D environments allow to view practical content in an active way [20]. Because of that, the VR interactivity and feedback are also useful to achieve high learning rates [21]. Moreover, VR offers a closed world where the users could feel more privacy, comfort and confidence than in a normal classroom [22]. Lastly, people have different ways of processing information. VR can bundle activities for different ways of learning and be adapted to a larger audience [16].

Several studies investigating SpLDs and videogames have been carried out. For example, Peters et al. analysed the visual training of dyslexia difficulties through action games [23]. They concluded that reading accuracy, speed, and comprehension were significantly improved. For this reason, action games were considered as a fun and engaging intervention for dyslexia. Other authors developed adaptative SG for different SpLDs [1]. The results showed positive feedback for the game ability to personalize to the needs of the player. They also defined a range of criteria for the development of serious games for children with SpLDs. In the first place, games should be geared toward children who can read and write. Moreover, the games must be easy to understand facilitating the children work. To conclude, it is necessary not to distract the children's attention in order to keep them focused on the main task.

Most of the studies that use video games as a treatment for dyslexia are focused on an audience between 5 and 14 years old. During these ages, the intervention may obtain the most significant benefits because children are undergoing rapid neural development and the attentional networks are still maturing [24]. Several reports ensure reading improvement using computerized games and applications that work with spatial and temporal attention [25]. Nevertheless, there are hardly any studies using an immersive VR-SG for the treatment of dyslexia. These studies have no significant results because they have no control group to compare the results, or the sample is formed for less than 30 people [26, 27].

## 3 Game design: DixGame

DixGame is an immersive virtual reality serious game. The aim of this game is to work on the reading and writing needs of children with dyslexia. The chosen target audience for this game is children with dyslexia between 8 and 12 years old. This age range was decided to have some master language and the ability to learn to use the game without

difficulty [24]. This game is constituted by two games: a whack-a-mole and a memory. The game's environment is a funfair; therefore, children may associate the game with favorable emotions. Gamification and positive reinforcement of this game are two key issues so that children do not get bored, frustrated, or feel evaluated. Therefore, a system of rewards and positive messages is offered throughout the game. The evaluation system is included in each game. Each of these levels has a progressively increased difficulty. It will be examined if the children are improving their reading and writing skills in case, they pass the proposed levels. DixGame was developed according to the flowchart proposed for the design and implementation of immersive VR-SG described in another paper of the researcher department [28].

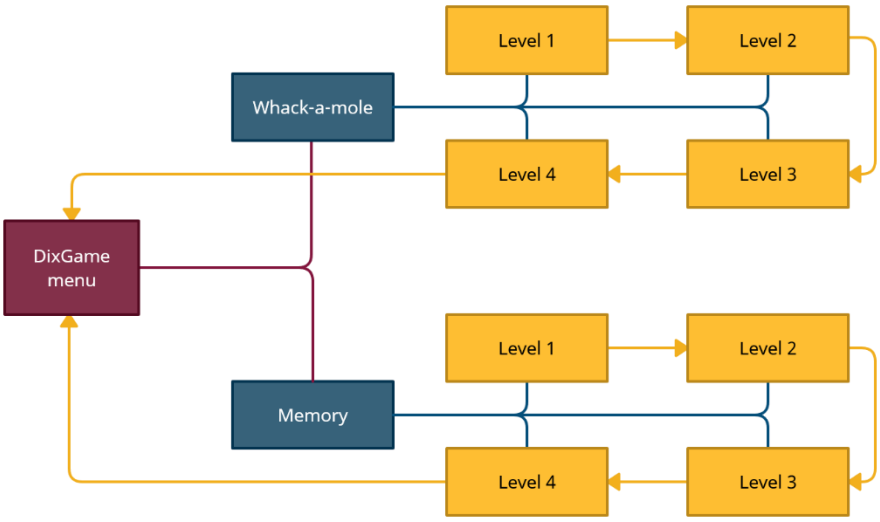


**Fig. 1.** DixGame Flow chart for the recommended progressive learning

In order to make possible an autonomous learning, Whack-a-mole and Memory games have got various levels of progressive difficulty. Figure 1 shows the diagram of the game. Blue rectangles indicate each of the games, and yellow rectangles show their levels. The recommended itinerary for progressive learning is indicated with yellow arrows. Nevertheless, the professional or the player are able to choose another game route.

### 3.1 Software

DixGame has been developed using the source code and the scenario of a game from Lightspeed Studios called Nvidia® Funhouse. These resources are available for developers for free on Steam platform. Mod Kit of the game can be reached via the Epic Games launcher. This game has been used as a tool to save time and resources using

the environment and objects. Nevertheless, several modifications have been done to adapt the game to the requirements and objectives of DixGame.

The textures of the original moles in Whack-a-mole game have been replaced by colours, letters, or words to adapt this game (Figure 2). The posters have also been changed to make the game more focussed on the educational field. Some messages have been included to explain how the game works, the task of each level, and to encourage the player. Furthermore, the game has been programmed to recognize the correct moles and to come out in pairs each time. Figure 3 shows some of the changes that have been made.


**Fig. 2.** Mole's textures modifications

To design the Memory game, cards with different textures have been created and placed on a wood-table. The cards have a letter and a colour on one side and a design that matches the environment on the other side, as it can be seen in Figure 6A. DixGame has been programmed so the cards can only be picked up two at a time. The game is able to recognize when a pair is correct or not. If the pair is correct, the player receives a positive reinforcement message but if it is not, a "Try again" message appears. In this way, the child is encouraged to keep playing and learning with the game. In both games, different buttons have been created to allow to restart the levels if needed or to go back to the main menu and select another level (Figure 4A, Figure 6C).


**Fig. 3.** Modifications between the reference game and DixGame

The game engine used to develop DixGame was Unreal Engine with the 4.26 version. Unreal Engine is free and easy to use for people who do not know how to program with code because of its programming through nodes. Moreover, Unreal get realistic results, which is important to acquire a better level of immersion. The 3D models needed for the game have been created using Blender 2.91. Moreover, Adobe Photoshop has been used to produce the textures of these elements because of the knowledge of the program and its ease of use.

All these software have been chosen because of the previous and satisfactory experience of the researcher group in the development of educational applications [13, 21, 29].

### 3.2 Hardware

This game has been developed for any of the desktop Head Mounted Display (HMD) from Oculus. The user interacts with the game through the controllers that act as the user's hands in the virtual world. The right joystick is used to move around the scene and the left joystick to rotate the view. The user can grab the objects by pressing the side triggers as it simulates the movement of closing the hand. An Oculus Rift S headset was used fot the beta test.

Whack-a-mole

In the Whack-a-mole game, the player must hit different moles with a mallet (Figure 4F). This game aims to work on the attention and visual and reading agility. The moles will appear in front of the child when the game is started (Figure 4C). A series of challenges will be proposed to the player, and they must be completed to finish the game (Figure 4D). The player will receive or lost five points each time a mole is hit correctly or incorrectly (Figure 4E). The player wins the game when 150 points are attained. Furthermore, a series of light bulbs will indicate the remaining of time (Figure 4B). If the correct moles are unhit, every two seconds, one of the bulbs will turn red. When every bulb is red, the player will lose the game.


**Fig. 4.** The appearance of DixGame's Whack-a-mole

There are four levels of difficulty. The first one is a simple level where children must strike the moles with the colour that is requested (Figure 2B). The simplicity of this level allows the child to adapt to the environment and understand how the game works in a visual way. Moreover, it provides a sense of fun because it hardly includes educational content. In the second level, the moles have different letters. The child is asked to hit only those moles with a specific letter. These letters are clearly identifiable for a child with dyslexia (Figure 2C). In the third level, the challenges are similar to the previous one. The letters' identification is more complicated and different fonts, uppercase and lowercase are mixed. In the last level, each mole has a word or a pseudo-word, such as "moon" or "noom" (Figure 2D and 2E). The challenge in this level is to hit just the words that are correctly written. As Figure 5 shows, the speed of the moles will increase progressively in every level to increase the difficulty and encourage the player.


**Fig. 5.** Programming of level speed in Whack-a-mole game

### 3.3 Memory

The second game of DixGame is a memory where the player must pick up sixteen cards from a table to pair them off (Figure 6A). These cards have different letters, colours, and fonts to make the player work on his reading and writing needs. Moreover, this game aims to improve memory and attention skills. A countdown has been included so that the child is aware of the passage of time and learns to manage it (Figure 6B).


**Fig. 6.** The appearance of DixGame's Memory

In the first level, a colour is assigned to each pair of cards to make easier for the child to match them up in a visual way. Furthermore, the letters in this level are very different between them to achieve this goal. This level wants to teach the player how the game works and show the playful component of this educational game. The second level is slightly difficult than the previous one. It has some duplicated colours without enlarging the similarity between the letters. In this way, the player could feel the increase of difficulty but without getting frustrated. Colours of the previous level are maintained in the third level; therefore, letters are more similar with each other. Finally, in the fourth level every card has the same colour, and the letters are very similar. For example, “p”, “b”, “q” and “d” are present in this level. In each level, the time that appears on the countdown is less than the previous one to increase the difficulty progressively. In order to progress through the recommended itinerary, the player must work on their difficulties and gradually improve with levels.

## 4 Conclusions and future work

DixGame has been created for the treatment of dyslexia for children between 8 and 12 years old. This is a virtual reality serious game that has two games inside: Whack-a-mole and Memory. These inner games pretend to improve some reading and learning skills of children with dyslexia. Whack-a-mole has been developed to recognize the letters and words depending on the proposed challenges in each level. Additionally, this game works on attention and visual and reading agility. However, Memory aims to improve memory and attention skills by pairing off letter-cards. To face these purposes, a game done was taken as a reference: Nvidia® Funhouse, to economize the resources. This open-code game had been modified to turn into this tool for dyslexia treatment.

It has not yet been possible to perform a proper usability test with a public target group. In the near future, DixGame will be tested by children between 8 and 12 years old with reading and writing difficulties to evaluate the performance of the already developed games. The children will try the game levels according to their needs for about twenty minutes. Subsequently, they will fill a satisfaction and usability questionnaire about the experience. Based on the answers obtained, the games will be modified so that they were able to obtain better results. In addition, it will be adapted to the needs observed in the experience according to the player’s age, the game difficulty, the balance between fun and learning, etc. The update game pretends to be more useful for the treatment of dyslexia. The game will also be adapted so that it can be used on more HMD devices like HTC Vive so that more people can utilize it. Furthermore, they will be developed some more games that help to work on reading and writing skills through other types of exercises. For example, a game based on word formation through spelling.

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