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# *Development of an Augmented Reality based Serious Game for the Training of Children with Dyslexia and Dysgraphia*

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***Abstract:*** Therapists have used paper-based exercises to treat learning disorders for many years. Dyslexia and Dysgraphia are one of the reading and writing disorders that are common nowadays. Different serious games and interventions are developed for the improvement of dyslexic and dysgraphic children. But these games cannot engage these children for a long time. Moreover, there is a need for an assessment criterion for the performance of dyslexic and dysgraphic children. Augmented Reality is an emerging technology that is used in the educational and medical fields. Augmented Reality in learning apps increases children's performance and makes them attentive. Research shows that it has a positive impact on dyslexic children. In this case study, an augmented reality-based serious game called ARLexic Game is developed to train children with Dyslexia and Dysgraphia. Design Science Research Methodology is used to design and develop the application. An experiment is conducted with specialists in special education and children with dyslexia and Dysgraphia aged 7 to 14 years old. The outcome shows that the ARLexic Game engagement level increases with time. Children learn quickly without being bored and enjoying it.

***Keywords:*** Serious Game (SG), Augmented Reality (AR), Dyslexia, Dysgraphia.

## 1. Introduction

In several cases, the detection of attention deficit hyperactivity disorder (ADHD) in children is normally related to poor academic performance, low levels of engagement with educational tasks, and specific learning difficulties (SLDs) (e.g., Dyscalculia, Dyslexia, and Dysgraphia) [1]. According to American Psychiatric Organization, dyslexia is defined "as a specific learning disorder, affecting around 5% to 15% of the world population [2]." Dyslexia is a neurological learning disability categorized by problems with word recognition and poor spelling [3]. Dyslexic Children mostly struggle with their language skills, including word recognition, comprehension, spelling, and pronunciation [4]. They are not able to detect spelling errors deliberately [5]. Dyslexia in children is not related to a desire to learn or lack of intelligence and occurs with different intellectual levels [6]. Dyslexic Children can learn reading skills and interpret words with proper training, but they need more time and practice to acquire them [7]. Dysgraphia is "a condition in which a person has difficulty expressing thoughts in written form and the inability to recall patterns of alphabets or symbols [8]." Dysgraphia is a writing difficulty, so it does not just relate to poor

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handwriting but is also characterized by writing skills that are significantly less than the given estimated person's measured intelligence, chronological age, and age-suitable education. The estimated frequency of developmental writing disorders is nearly 7-15% among school-going children [9]. Augmented Reality (AR) can be defined as an emerging technology in which, during the user's experience, virtual objects are attached to the real world in real-time. "An Augmented Reality system should: (1) combine real and virtual objects in a real environment; (2) run interactively and in real-time; (3) register real and virtual objects with each other [10]." The interaction styles are improved with advancements in technology, from using a mouse and keyboard to interacting with your whole body [11]. On the other hand, the AR application can simply work with smart devices and gives a more global approach to the involvement of children [12]. Augmented Reality gains the attention of children with ASD (including dyslexia) and increases their involvement in AR-based applications [12], [13]. The AR-based applications or games support a multimodal interaction for dyslexic children as a part of therapy sessions or intervention [14]. AR enhances children's abilities to understand concepts and helps them to visualize things, places, and names [15]. Companies have been gradually using Augmented Reality as an advertising tool for displaying their products and services in the market. Consumers' decision-making companies like Ikea Place use AR applications to enable customers to place the company's furniture as they imagine them in their homes [16].Serious games (SG) have been widely used to advance therapies for various learning disabilities. Several benefits of "SG have been reported, through improvements and effectiveness on students, increasing their positive attitudes, motivation, self-perception, and problem-solving approaches [17]." Towards the specific tasks, game-based interventions are applied to attract users. These interventions engage the users with amusement and entertainment because they are interactive computer applications. But these interventions satisfy the target with less effort [18]. Games for dyslexic or dysgraphic children generally apply different activities attached to a single visual screen by using different gaming elements [19].

In this paper, we define the terms Dyslexia, Dysgraphia, Augmented Reality, and Serious Game and Sustainable Development Goals in the first section. The second section consists of the Design and Development process of Augmented Reality based Serious games. The third section comprises the research methodology, and the last section describes the conclusion of the case study.

## 2. ARLexic Game Design and Development Process

We followed the Design Science Research Methodology (DSRM) proposed by Peffers et al. [18] for this research work, illuminated in Figure 1. It has six steps used to solve the specific problem and achieve the framework for developing an Augmented Reality-based Serious Game for children with dyslexia and Dysgraphia. The six steps of DSRM are as follows:

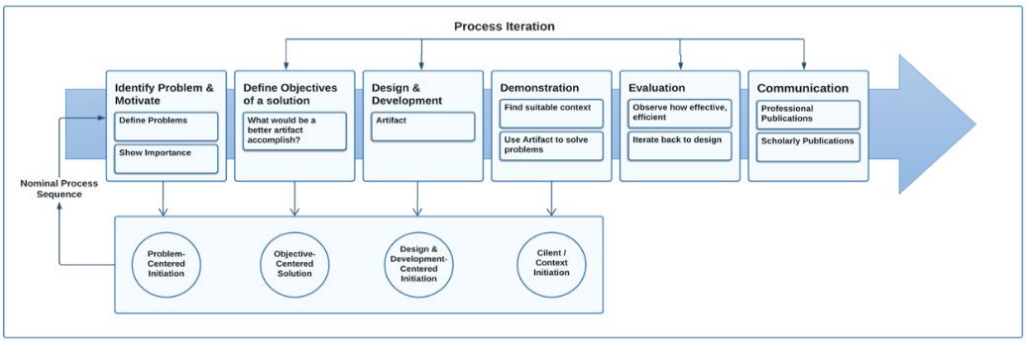


Figure 1: Design Science Research Methodology (DSRM) [20].

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**Step 1: Problem Identification and Motivation.** In various countries, specialists do certain tests to identify and train Dyslexia and Dysgraphia in children. They perform this test by using the simple paper-and-pencil method. Because of the specificities of these tests, it requires individual assessment time. Also, each one needs special attention from the teacher.

**Step 2: Define the objectives of the solution.** This research work aims to design and develop an augmented reality serious game for the training of children with Dyslexia and Dysgraphia. The Serious Game can be used on smart devices like tablets and smartphones, and the augmented reality feature adds playfulness and attractiveness besides the training of children.

**Step 3: Design and Development.** The details of software and tools used to design anddevelop the ARLexic Game are discussed in the development stage. We chose the Unity 3D gaming engine to develop SG combined with Playmaker visual scripting tool. For the augmented reality application, we use the Vuforia engine by implementing Vuforia SDK in Unity 3D. For the graphic designing of the ARLexic Game, we use plenty of tools, including Adobe Illustrator, Adobe After Effects, and Paint3D. We use Blender 3D for modeling Virtual objects and 3D Alphabets.

**Step 4: Demonstration.** To demonstrate our AR-based Serious Game, we experimented with testing the platform with the selected group of children. We also perform usability testing techniques to evaluate our application.

**Step 5: Evaluation.** The evaluation of our application has empirical phases. We will observe the progress in some dyslexic and dysgraphic children and their teachers and professionals.

**Step 6: Communication.** The research will be published in conference papers and computer science and education journals.

## 2.1. ARLexic Game Gameplay

First, the therapists explain to the children how to play the game and show them a tutorial. The main menu consists of three options choose the Game, show the character, and exit the Game. The ARLexic Game starts with the main character called "Memo the fish." The 3D model of the main character engages children's interest in the Game (Figure 2). Then the children choose either to play the word game or to view the 3D Alphabets in AR view. The children learn the Alphabet in 3D view by scanning the target images. The word game consists of two levels, Easy and Difficult. The words consist of 3 to 4 letters and the respective picture at an easy level, and the picture makes it easy for children to guess the correct spelling of the word.

Similarly, there are 5 to 7 letter words in the difficult level, and a timer of 2 minutes is added to the screen on each level. If the children complete the word within 2 mins, the next word shows up; otherwise, the “KEEP GOING” message pops up. In this way, the teachers or the therapists know how much time the children have taken to solve the task.

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Figure 2: Screenshots of Main Menu and AR view.


Figure 3: Screenshots of Word Game.

## 3. Research Methodology

### 3.1. Participants

This study evaluates five children with dyslexia and dysgraphic children aged 7 to 14 years old for ARLexic Game. The children are selected from Syeda Khatoon-e-Jannat Trust Hospital and Special Education (see Figure 4).

Figure 4: Training of dyslexic and dysgraphic children with ARLexic Game.

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### 3.2. Procedure & Results

During the session, the activities performed by dyslexic and dysgraphic children are recorded. First, we gain their focus by showing them the 3D model of "Memo, the Fish." We collected the following evaluation measures.

1. The total time expended by the dyslexic and dysgraphic children to perform the tasks proposed by the ARLexic Game.
2. The user engagement rate of the children with the ARLexic Game.

Engagement Rate = Total Active Users over a certain period of time/Total Users (1)

3. Children's comments while playing the ARLexic Game.

We observe the children's engagement from the measures of 0 to 5 at three different levels, as shown in Figure 5. We have five total users for our ARLexic Game. From the observations, we found out that only four users were engaged with our app for 45 min. Hence, the User Engagement Rate of ARLexic Game is 0.8.

Children 1, 2, and 4 are active and complete the tasks while using the ARLexic Game. While Child 5 do not take part in any of the activity. The duration needed to complete task 2, the word game, is 10 mins. Besides recording the experiment, children's attitude shows that they enjoy the ARLexic Game. However, they also face some difficulties in moving to another word. Thus, the Game required some changes in feedback and navigation in AR Camera. AR-based UI's (User Interfaces) differ a lot from traditional GUI's (Graphical User Interfaces) [21], so it may get difficult for dyslexic and dysgraphic children to use AR applications. For this, we have to define usability guidelines for AR applications in the future.

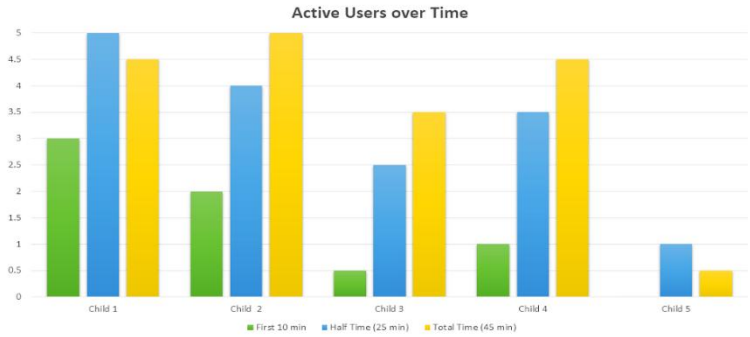


Figure 5: Clustered Column Chart of Active users over three different periods.

Table 1 shows the results of the ARLexic Game activities. The actions can be measured as Complete (C), Incomplete (IC), and Complete with help (CH).

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Table 1: Results.

| Children | Task 1 (AR Alphabets) | Task 2 (Word Game) | Time expended in the ARLexic Game (Word Game) | Children's Comments while playing with the ARLexic Game |
|---|---|---|---|---|
| Child 1 | C | CH | 14 min | It is amazing how the Alphabet is shown in the air. |
| Child 2 | C | C | 12 min | I am enjoying it. |
| Child 3 | CH | IC | 21 min | I like "Memo the Fish." |
| Child 4 | C | CH | 17 min | How are the alphabets shown in the air? Is it magic? |
| Child 5 | IC | IC | --------- | -------- |

## 4. Conclusion

This paper presents the design and development of an AR-based Serious Game named ARLexic Game to train children with dyslexia and Dysgraphia. As mentioned previously, we experimented with dyslexic and dysgraphic children for a session of about 45 mins. The purpose of this experiment is to check the engagement level of the ARLexic Game and get to know the comments of the children.

The results show that the engagement of each child increases with time due to Augmented Reality. The dyslexic and dysgraphic children enjoy learning with AR-based Serious Game. We are at our initial training stage. So, we will experiment with completing the training session and compare the results in the future. The experiment should be conducted with more participants for better results. We will also improve navigation in AR Camera and include some social features in the near future. After the validation of the ARLexic Game, it will be offered to the community.

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