A Virtual Reality Prototype for Dyslexia

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Abstract

Worldwide, it is estimated that 5% to 10% of the population has dyslexia, a learning disability that impacts language-related processing skills, giving as a result low academic results. At the same time, the use of virtual reality technologies is growing in many areas, such as education. In this demo, we present a custom-made software designed to collect data from people with dyslexia in virtual reality environments. To make sure that the tool is feasible in a school context, we performed a user study with 22 Hungarian children to support us throughout the design process of the software. Early results show a promising acquisition of data and a positive virtual reality experience for this target group. This method presents a novel approach to acquire data from this target group to be used for inclusion purposes such as screening or treating dyslexia.

Keywords: dyslexia, virtual reality, eye-tracking, data collection, gaze detection.

1 Dyslexia

Dyslexia is a cognitive disorder that affects reading and writing skills. Even if it is universal, the prevalence of dyslexia depends on the language that is used. For instance, in the native English-speaking population, it is estimated to be between 5% and 12% [14] while for the Italian and Dutch languages this number is 3% and 5% respectively [2]. Identifying and treating dyslexia is crucial for the further development of the child and would reduce the high risk of academic failure that is associated with dyslexia.

Virtual Reality (VR) is a relatively new technology that enables individuals to immerse themselves in a virtual world that appears to be real. This environment is perceived through a headset or head-mounted display. The use of VR is growing; in fact, the VR market worth 10.5 billion U.S. dollars and it is expected to expand drastically in the coming years [16].

Screening and treating dyslexia in children or adults is not an easy task; it is expensive, requires the services of a specialist, and takes time to perform. While VR has profoundly impacted many areas such as video gaming, medicine, culture, and education; the intersection of dyslexia and VR is still a novel field. In this demo, we present an innovative solution, that, to the best of our knowledge, is the first to use VR to collect data from this target population.

1.1 Related Work

Virtual Reality is increasingly being used in accessibility-related fields targeting dyslexia. Kalyvioti and Mikropoulosa [6] designed a screening process, employing VR to study characteristic memory difficulties between a group of people with and without dyslexia.

In total, 14 participants were included with an equal split between the control group and the number of participants with dyslexia. Their results show that there were no significant differences between the performance of students with and without dyslexia.

Brunswick *et al.* [3] tested the hypothesis that dyslexia is associated with visuospatial advantage and involved 20 participants with dyslexia and 21 without dyslexia. Their results show no evidence that the participants with dyslexia outperformed those without dyslexia. Smyrnakis *et al.* [15] proposed a method named ‘RADAR‘ that is capable of identifying children who are at risk of having dyslexia based upon eye-tracking measures retrieved by a custom-made eye-tracker. In spite of the fact that the results are encouraging, the participants were asked to place their head on a chin rest, limiting head movement and the somewhat slow and inaccurate eye-tracking camera reduced the data quality.

All previous work highlight the need of more data. Hence, this work combines VR and data acquisition from people with dyslexia for further research purposes while providing free movement and a more enjoyable experience while testing.

2 Our Prototype

The concept of virtual and augmented reality has been around for decades and expressed in the literature since the late 1990s [1, 9]. It is only recently, however, that the technology is emerging onto the consumer market and not solely available for research opportunities [4]. Recent advancements within the immersive headset market enable eye-tracking features that were, up to recently, only possible against a high cost. The gaze data output frequency and accuracy for these built-in eye-trackers are several times better in comparison to the hardware used in research only done a few years ago [13]. In contrast to previous eye-tracking studies, where participants were asked to assume a particular position, a VR headset has the added benefit of providing unconstrained use and free movement.

In this work, we use the HTC Vive Pro Eye VR head-mounted display from HTC with an eye-tracking sample rate of 120Hz. Following we describe how we design (i) the software prototype and (ii) the measures our software collects.

2.1 Immersive Environment and Design

In order to collect useful measures that address dyslexia, the VR environment replicates a reading experience in a classroom-like setting in which participants read two short stories. The website `lingua.com` provided the textual content for the reading exercise, and the difficulty of the text was deemed appropriate for the target age group by a teacher in the Netherlands. Each story was concluded with five questions within the VR environment to assess the story comprehension. The participants were positioned one meter away from the board at an appropriate height for an average child sitting down.

Except for the textual content, the rest of the VR environment is entirely language-independent, meaning that this software can be easily adapted to different languages. Since the text layout can affect text readability, especially for people with dyslexia, the text layout can be adjusted to accommodate different fonts, colours, and sizes. For the reading exercise, we used the Liberation Sans font with a font size of 36 and white letters on a blue background. Different studies recommend using Sans Serif fonts, together with white letters for people with dyslexia [11, 12].

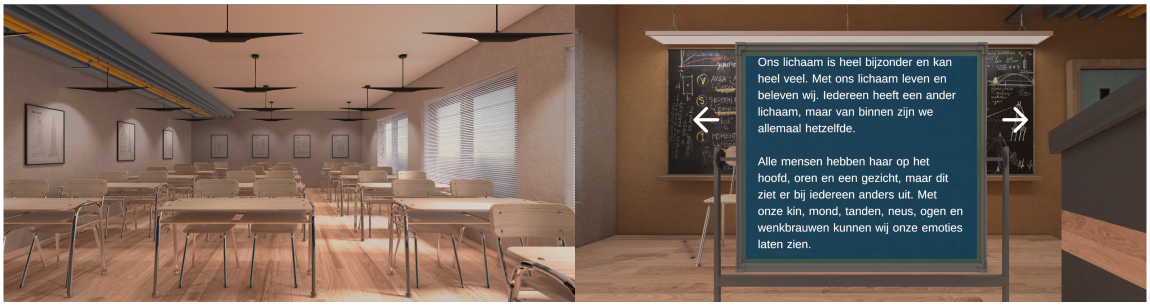

Figure 1: On the left, the empty classroom to signify calmness, on the right, the blue board optimized for reading.

2.2 Data Acquisition Design

The measures were designed to be used as features for machine learning purposes. Since eye-tracking software is expensive and difficult to validate, we developed a custom-made software that is capable of extracting eye-tracking measures from existing Software Development Kits (SDKs) and Application Programming Interfaces (APIs). This approach presents us with multiple advantages: it provides us with fine-grained control of detecting fixations and saccades, and it is capable of generating more relevant dependent measures in relationship to readability in comparison to commercial software.

The current implementation responsible for collecting the measures depends on the Tobii Pro SDK and transforms the raw output into x and y coordinates. It further determines what data is useful to keep and what data should be dismissed. It does this by defining a region of interest and using the interface elements as reference points. (See the arrow elements in Figure 1).

We used an open-source R package called saccades[1], that utilises a velocity-based al-

[1] Saccades, created by Dr Titus von der Malsburg: https://github.com/tmalsburg/saccades

gorithm, to detect saccades[2] and fixations[3], and from there compute the measures using the Go programming language [8]. Past studies involving eye-tracking hardware and persons diagnosed with dyslexia indicate that the eye-moments show a reflection of the difficulties that they experience while reading and processing language [5, 10]. The computer measures were chosen after reviewing different studies involving people with and without dyslexia.

- **Reading Time (seconds)**: the time it takes a participant to read one text passage.
- **Fixation Count**: the total number of recorded fixations.
- **Total Fixation Duration (ms.)**: sum of duration of all separate fixations.
- **Mean of Fixation Duration (ms.)**: mean of duration of all separate fixations.
- **Rightward Fixation Count**: number of rightward moving fixations.
- **Leftward Fixation Count**: number of leftward moving fixations.
- **Rightward Fixation Duration (ms.)**: sum of duration of all rightward moving fixations.
- **Leftward fixation Duration (ms.)**: sum of duration of all leftward moving fixations.
- **Regression Percentage**: ratio of leftward moving fixations to the total number of fixations.

[2] A saccade is the quick movement of the eye between fixation points.
[3] A visual fixation is the focused gaze on a single location.

3 Evaluation

Since we plan to use this tool for research in a school context, we carried out a user study in a school class composed of 22 Hungarian children. The prevalence of reading difficulties in a school class is expected to be between 5-15% and the children were all part of the same class (group 4) and were, therefore, representative of the population; the children had a mean age of 8.77 years old with a standard deviation of 0.66.

To better understand what kind of environment children would prefer during a reading exercise, we conducted an open question questionnaire using the think-aloud protocol [7]. The most important design decisions were related to keep the environment as familiar and recognisable as possible, because if the Virtual Reality (VR) environment was too exciting, the reading exercise would fail.

One of the conclusions of the user testing was that a classroom-like setting, although dull, was the most appropriate VR environment. It was essential for the reading exercise to be the focus and main stage of the experiment even though the participant is inside a VR. A considerable amount of testing and user evaluation was done on the blue board to make sure that the dimensions and position of the blue board were optimal for the head-mounted display. For example, the angle of the board was optimised for reading while sitting down, with the average height of children in mind. User evaluation also showed that it was important to showcase the empty classroom to calm the participant adequately before they start the experiment (see Figure 1).

The emphasis of the VR experience was to let the participant look around freely and have a sense of loneliness when first seeing the empty classroom. We accomplished this by incorporating a rotating chair in the experiment so that the participant can face the empty classroom first and then physically rotate in the VR environment, without making the participant feel nauseous. The visually-induced perception of self-motion can cause virtual reality sickness, and this was avoided by using a rotating chair.

During this evaluation we also checked that the eye-tracking measures were collected correctly by our prototype.

4 Conclusions and Future Work

In this work, we have presented a solution that can reliably collect and process eye-tracking data from a VR headset; we also have designed a set of measures that are extracted from this data. A user evaluation of the prototype provided us insights such as that a classroom-like setting is the most appropriate setting for children to undertake a reading exercise. Our prototype can be used for further research for dyslexia.

In the future, we plan to use this virtual reality-based software to collect data from students to address two novel approaches in the field: (i) to screen for dyslexia using a VR and machine learning and (ii) to make a text more accessible in a VR environment by adapting the layout in real-time.

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