

The Effect of Matching Learning Material to Learners' Dyslexia Type on Reading Performance



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1 Introduction

Learning disability is a general expression that covers disorders related to difficulties in various skills and senses. These difficulties may impact multiple abilities, such as reading, writing, listening, and speaking. Individuals, typically, suffer from such disorders due to a developmental issue. It is common for other factors such as sensory impairment and behavioral or other cognitive problems to co-occur with dyslexia [1].

Reading is one of the most important basic skills [2]. It can be considered as the gateway to learning other concepts. Most readers quickly learn to understand written text automatically and without any conscious effort. However, a percentage of readers face difficulties and tiredness when reading. This can lead them to be excluded socially and educationally, especially in classrooms [2]. Such readers are known as dyslexics. Dyslexia was first identified more than 100 years ago by Berlin [3].

Dyslexia is defined as a specific learning disability, widely believed to arise from a neurobiological issue. Dyslexics suffer from a disorder in the phonological component of language processing which leads to the following: (1) inaccurate and/or slow word recognition, (2) misspellings, (3) poor decoding ability [2], (4) word repetition or addition, and (5) character deletion and transposition [4].

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Myklebust was the first person to suggest classifying developmental dyslexia into different types [5]. These early classifications tended to classify dyslexia based upon symptoms. This helps in understanding the difficulties and thus in providing more appropriate support [5].

On the other hand, [5] suggested classifying dyslexia based on the dual-route model for single-word reading and predicting dyslexics' symptoms based on problems with components of this model. This model has proved the most effective and widely used for predicting the various types of dyslexia [6]. Therefore, this classification of dyslexia is adopted in this research.

The potential of online learning has increased due to the emergence of new technologies. Online learning can be defined as accessing learning materials via the Internet in order to interact with the instructor, the learning content, and other learners. Among the benefits of online learning are that the learner can access it independently of time or location [7].

However, this way of learning will not, necessarily, provide learning material that suits an individual's needs. Each dyslexic is different and thus should be offered learning material matched to their individual needs. Adapting online systems has the potential to achieve this and to improve the quality of learning and the user's experience. Generally, adaptation means a procedure for customizing something to the users' needs [3]. In learning, it is often described as organizing the learning to accommodate learners' differences [8] or to change its behavior based on learners' needs [9].

Dyslexics are affected by the language they are learning – the differences in language structure and orthography have a large effect on the difficulties that learners face. There has been little research into supporting dyslexic students in Arabic. This research targets teaching reading skills to young, native Arabic-speaking dyslexics.

The Arabic language is the sixth most spoken language in the world.¹ Over 200 million individuals speak Arabic as their first language. It is also used as a second language by millions of Muslims [10]. The cursive nature of the script, the use of diacritics, having multiple forms for a single letter (depending on the position within a word), and non-vowelized text are some of the particular problems when reading Arabic [11].

This research is concerned with the evaluation of the effects of adaptation based on vowel dyslexia (VD). The TrainDys system adapts learning material to learners' needs. The evaluation is in terms of a controlled experiment to investigate whether matching the learning material to the type of VD improves learners' learning and increases their satisfaction. VD and short vowel dyslexia (SVD) were chosen because of their frequency [6].

This paper is organized as follows: the related work is presented in the next section, followed by a description of the experimental design, and finally, the

¹http://www.ethnologue.com/ethno_docs/distribution.asp?by=size. Accessed on June 2020.

experiment's results are presented and discussed along with recommendations for future work.

2 Related Work

Few research studies have investigated the use of adaptive online education systems for dyslexia in the Arabic language. Some have developed applications, while others proposed frameworks and guidelines. In terms of applications, most studies use game-based techniques. A variety of evaluation methods have been used. Ouherrou et.al [12] developed a standalone educational game to assess dyslexics' skills in Arabic. The application was evaluated by specialists using heuristic evaluation, and a questionnaire was used to get feedback from dyslexic children and teachers. They found that the educational game was useful and that the learning process might benefit.

Another study by Al-Ghurair and Alnaqi [13] aimed to enhance dyslexics' short-term memory through a game-based application structured around a story. Its usability was assessed through observation of children's interaction and of their use of the system. The children's opinions were taken after using the system. They report that the children were satisfied with the interface's theme and that the children enjoyed the application and were engaged.

There has been some work on tools related to dyslexia in Arabic. Aldabaybah and Jusoh [14] proposed a set of usability features to improve assistive technologies for Arabic dyslexics. They applied these in a prototype which was then evaluated by a special education expert. They suggest that the added features increased the students' perception of usability and enhanced their academic performance. Benmarrakchia [15] proposed a set of design guidelines based on dyslexics' spelling errors. These guidelines covered four areas: visual ability, phonological processing, orthographical similarity, and cognitive processing. However, the evaluation of these guidelines is left to later studies. AlRowais [16] developed a framework for the evaluation of training tools for Arabic dyslexics. This uses experts, interviews, and questionnaires. The evaluations were mostly positive, but they did identify unnecessary elements, gaps, and necessary refinements.

Overall, there is limited research into technological support for dyslexic education in Arabic. There are many gaps, and most of the work treats dyslexia as a single class. However, it is clear that there are many different classes of dyslexia and that these each require different adaptations. Finally, in terms of evaluation, most research either has a very limited evaluation or none, at all. Qualitative approaches (such as interviews and observations) are most common with very few quantitative and controlled studies and little that assesses the learning gain or the effect on students' satisfaction.

3 Method

In order to investigate the effects of matching learning material to learners' dyslexia type, we developed a training system (TrainDys) and used this to run a controlled experiment to assess learning gain and learner satisfaction.

3.1 Setup

The TrainDys system was designed and developed. There are eight exercises each with ten levels giving a total of 80 words. Most dyslexics have a visuospatial/kineshetic style [17], so a multisensory approach was used [15]. For each exercise, a word is spoken by the system, and its image is displayed along with three choices. If they choose the correct word, positive verbal feedback is given [15], and they gain a point. Otherwise, they are asked to try again [18]. The learner needs to achieve 80% [18] to unlock the next level.

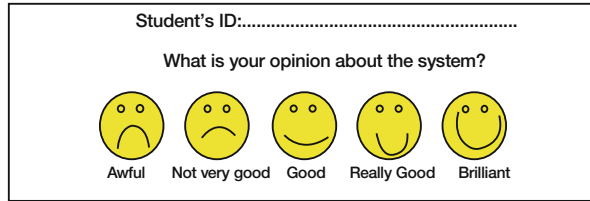
The material was chosen from the primary school curriculum to target vowel dyslexia. It uses a combination of short vowels (fat-ha, dammah, and kasra) and long vowels (a, i, u), (أ، إ، ؤ) progressing from simple (words of three letters and only fat-ha short vowel and alef long vowel) to advanced (five or six letters and a mix of the three short vowels and the three long vowels).

The cognitive theory of multimedia learning was used. The underlying theory was drawn from dual-coding theory, cognitive load theory, and constructivist theory [19]. Mayer and Moreno suggest five instructional design principles to achieve this: multimedia aids, contiguity aids, coherence aids, modality aids, and redundancy aids [19]. Each word is spoken and an image displayed (multimedia and modality aid), simultaneously (contiguity aid). The text was used to present the learning material (redundancy aid). No extraneous words or sounds unrelated to the learning material were presented (coherence aid). The TrainDys interface was designed following the guidelines for web design accessibility for Arabic content [20]. The experiment used these instruments:

- Diagnostic test: for diagnosis of dyslexia type.
- Consent form: parental approval since participants are under 18 years.
- Pre- and posttests: the first test to measure the knowledge level of the learner before using the system. The posttest was conducted after the course and used to calculate learning gain. Each test included ten words targeting VD (ten words of different lengths containing long and short vowels). For the posttest, a mixture of seen and unseen words was used.
- Satisfaction questionnaire: Because the subjects were young children, the smileyometer [21] was used (see Fig. 1).

Twenty learners were recruited. Due to the coronavirus pandemic, schools were closed partway through, and only 13 students were able to complete the

Fig. 1 Smileyometer [21]



experiment in school. Zoom meetings were used to complete the study remotely with 3 additional students, giving a total of 16. The remaining four learners did not complete the study for the following reasons:

- One learner’s parents refused remote participation.
- One learner refused, thinking they were on holiday.
- One learner had a poor Internet connection.
- One learner did not have a suitable device to conduct the experiment.

3.2 Procedure

The experiment was conducted in eight experimental sessions, each of 35 minutes. The study took place in Riyadh, Saudi Arabia. The experiment took place in person, in quiet rooms, in school. The three exceptional cases started as normal and were completed remotely using Zoom. The learner was first introduced to the study and completed the diagnostic test and pretest. They then used the TrainDys system. After finishing the study, they completed the posttest and satisfaction questionnaire.

4 Results and Discussion

The experiment was conducted with 16 female dyslexic learners; 8 were assigned to the SVD group (mismatched) and the other 8 to the VD group (matched). The learners were homogeneous in terms of knowledge level, age, and grade. They were in the fourth, fifth, and sixth grades in primary school. The mean age was approximately 10 (SD = 1.41) and ranged from 9 to 14. They were encouraged to take part in order to improve their reading.

4.1 Learning Gain

This shows that the learning gain of both the matched and the mismatched group was positive (posttest > pretest). This indicates that the reading of the matched group was

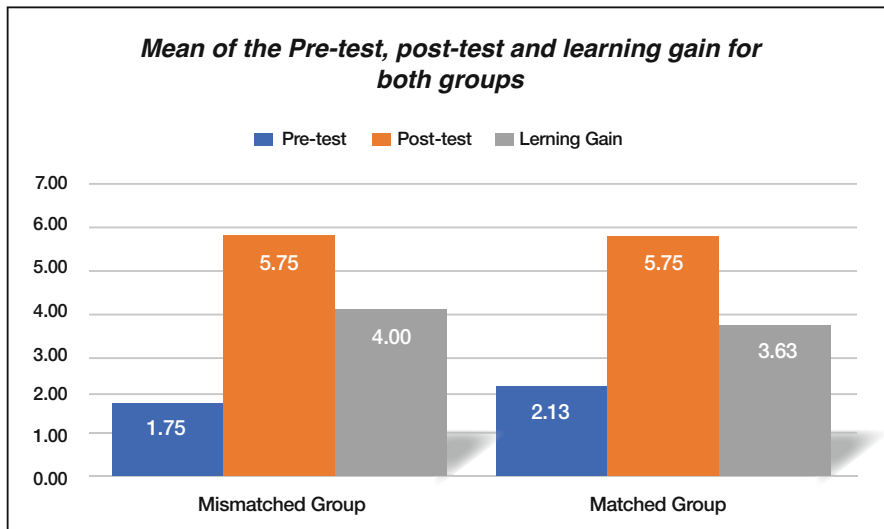


Fig. 2 Mean of the pretest, posttest, and learning gain for both groups

Table 1 Mean and standard deviation of the pretest, posttest, and learning gain

Group type	N	Pretest		Posttest		Learning gain	
		Mean	SD	Mean	SD	Mean	SD
Mismatched (SVD)	8	1.75	2.05	5.75	2.25	4.00	2.00
Matched (VD)	8	2.13	1.73	5.75	1.75	3.63	1.41

improved. This was also true with the mismatched group. The learning gain of both groups was, effectively, the same, and the posttest results were identical (Fig. 2). This result was surprising. It might be due to:

- The learning material not being new to either group: the main goal of the system was the reinforcement of a skill that had been taught earlier.
- The words used contained both long and short vowels. This will also benefit the mismatched group who have problems only with short vowels.
- The small number of participants.

The significance of the learning gain between the two groups was tested. As the data of the mismatched group was not normally distributed, as assessed by the Shapiro-Wilk test ($p = 0.034 < 0.05$), the Mann-Whitney U test was used as an alternative to an independent sample t-test. The difference in median learning gain for the matched group (3.50) and mismatched group (3.00) was not statistically significant: $U = 33.5$, $z = 0.163$, and $p = 0.878$.

However, these findings are true only for this sample of students and cannot be generalized due to the small sample size (Table 1).

Table 2 Mean, median, and standard deviation of the learner satisfaction

Group type	N	Learner satisfaction		
		Mean	Median	SD
Mismatched group (SVD)	8	4.50	5.00	1.41
Matched group (VD)	8	4.75	5.00	0.71

4.2 Learner Satisfaction

Table 2 shows the mean, median, and standard deviation of the learners' satisfaction for each group. The mean for both groups was almost the same, and their median was identical. The scores indicate that learners in both groups were very satisfied with the system, and so, it is not possible to detect any meaningful effect. This could be due to the interactive feature of the system and the guidelines that were followed during system design [20]. Again, these findings are true only for this sample of students and cannot be generalized due to the small number of subjects.

5 Lessons Learnt

During this experiment, several lessons were learned. It is very hard to recruit large numbers of students with an appropriate profile. We restricted participants to have a specific form of dyslexia, to be in one geographical area (for practical reasons), and to have similar ages and reading performance. The problems that arose through the coronavirus pandemic did disrupt the study. However, this also highlighted that it may be possible to conduct future studies remotely – and therefore to recruit a much larger number of participants across a wider geographical area.

In terms of the TrainDys system, there were several issues. The learning material did not discriminate sufficiently between the needs of the different students. There was also too steep a progression in the difficulty of the material. Each of these factors will be addressed in future work.

The instruments used also had some weaknesses and need to be refined. A particular problem was with the assessment of the students' satisfaction. The scores given by the students were extremely high. While this is reassuring, in terms of the quality of the learning material, it does mean that it is impossible to discriminate between the conditions. Again, this will need to be reassessed and refined.

6 Conclusion and Future Work

Dyslexia is a universal reading difficulty. It can be found everywhere and independently of language. However, just as everybody is different, dyslexics are too. They suffer from different reading problems. For instance, some of them may not

understand what is written, while others may omit, transpose, or alter letters while reading.

The aim of this research is to overcome these problems by providing dyslexic individuals with appropriate learning material that matches their needs. It is expected that this will improve their learning and their satisfaction. This, in turn, is expected to improve their engagement, which should have further benefits.

We designed a controlled experiment to test this. The students' dyslexic type was diagnosed, and their prior reading performance was assessed. They were then assigned to one of two conditions. Learning was delivered through an online system, and their reading performance and satisfaction were assessed after completing the course. The results showed an improvement in learners' reading performance in both conditions and very high levels of user satisfaction.

There has been little research into using adaptive learning for dyslexia in Arabic. This work seeks to explore the feasibility and benefits of this approach. The results of this preliminary study do not clearly demonstrate any benefit. Our further work will explore making the adaptation more useful and also expanding the number of participants.

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