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Alghabban, Weam Gaoud; Hendley, Robert

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The Impact of Adaptation Based on Students' Dyslexia Type

An Empirical Evaluation of Students' Satisfaction

Weam Gaoud Alghabban*
School of Computer Science
University of Birmingham
Birmingham, United Kingdom
wga814@cs.bham.ac.uk

Robert Hendley
School of Computer Science
University of Birmingham
Birmingham, United Kingdom
R.J.Hendley@cs.bham.ac.uk

ABSTRACT

Research based on dyslexia type adaptation has received little attention from researchers. What work there is, is often marked by a lack of well-designed and rigourous experimental evaluation in terms of its effectiveness, in general, and specifically of the satisfaction of students with dyslexia with their learning. A high level of student satisfaction is a significant indicator of a system's effectiveness, where it improves students' experience and motivation and, therefore, enhances their learning process. This paper aims to investigate how adaptation based on a student's dyslexia type affects their satisfaction. An adaptive e-learning system that adapts learning material based on dyslexia type was implemented. A controlled experiment was conducted with 40 students with dyslexia to evaluate their satisfaction level with the e-learning system. The results show that students were more engaged and satisfied with their learning experience when the learning content matched their dyslexia type. This indicates that adapting learning material according to dyslexia type can improve the satisfaction of these students and increase their motivation and experience.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; • **Social and professional topics** → *People with disabilities*; • **Applied computing** → *E-learning*.

KEYWORDS

Adaptive e-learning, Dyslexia type, Student satisfaction, Children with dyslexia

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*On leave from University of Tabuk, Tabuk, Saudi Arabia, Email: walghabban@ut.edu.sa

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1 INTRODUCTION

Dyslexia is a specific learning disability that causes challenges in reading and spelling [27]. It is one of the most common types of learning disability, occurring in all types of people regardless of culture, background or ability [37]. Its effects and their severity and prevalence does vary across different languages and orthographies [15].

In recent years, electronic learning, also known as e-learning, has gained broad acceptance in various educational fields. It provides a powerfully supportive environment for students with dyslexia by providing assessment, training or support for these users. Although e-learning systems may eliminate geographical distances and increase access flexibility [34], traditional e-learning suffers from some drawbacks. These systems do not consider different characteristics of individuals with dyslexia such as dyslexia type, skills, abilities and knowledge; instead, they tend to provide the same learning material in the same sequence to all students and ignore the different needs and expectations of the different students with dyslexia. This may lead the students to become frustrated, dissatisfied with their learning process or confused. This, in turn, impacts their satisfaction and engagement and, thus, affects the effectiveness of the learning.

The transition from traditional e-learning systems to adaptive e-learning systems has addressed some of these limitations. Adaptive e-learning systems can adapt the learning material and its organisation based upon different characteristics of students [11]. Among the characteristics of students with dyslexia, dyslexia type is recognized as an especially important factor in education [17]. Individuals with dyslexia are different, each with unique characteristics and reading problems [17]. Therefore, a learning environment should not treat them all in the same manner, but instead apply different approaches of treatment and teaching.

Several adaptive e-learning systems for dyslexia have been proposed, such as a dyslexia adaptive e-learning framework, which adapts itself according to the dyslexia type of students [7]. Another proposal has been an adaptive e-learning system that can personalize the learning experiences presented to students with dyslexia based upon dyslexia type, knowledge level and learning style [6]. In addition, an adaptive e-learning system based on learning style and cognitive traits of dyslexia has been suggested [10]. These are, though, just proposed frameworks. They lack an implementation and, in particular, a rigorous controlled evaluation with a useful number of participants.

There have been many proposals about how to use different factors related to characteristics of students with dyslexia to inform adaptation in e-learning systems [6, 7, 10]. However, adaptation

based on dyslexia type is still under-investigated. There is also a debate surrounding dyslexia in different languages [3, 6–8, 10, 30]. This, despite the fact that previous research supports the argument that individuals with dyslexia may have different characteristics resulting from different underlying causes [17].

Furthermore, the effectiveness of the learning process, and the enhancement of the satisfaction of students with dyslexia when learning material is adapted to match their dyslexia type, has received limited attention and the benefit remains unclear. This is important because extensive research has shown that there is a strong relationship between students' satisfaction and their motivation and engagement [34]. Previous studies in this area have also been marked by a lack of well-designed and robust experimental evaluations in terms of assessing both learning effectiveness and students' satisfaction [6–8, 10, 30].

Student satisfaction is an important indicator of a learning system's quality and effectiveness [19, 24]. It reflects the quality of their experience and a high level of satisfaction can lead to increased motivation and engagement [4].

This paper presents the results of an investigation into the impact of adaptation, based on dyslexia type, on the satisfaction of students with dyslexia. An adaptive e-learning system that adapts learning material based primarily on dyslexia type is implemented. A controlled experimental evaluation was conducted to measure satisfaction of students with dyslexia.

The rest of this paper is structured as follows: Section two covers the theoretical foundation of developmental dyslexia type. Section three presents dyslexia type-based adaptation. Section four details the experimental evaluation. Section five presents the results. Finally, Section six concludes the paper and points to future work.

2 THEORETICAL FOUNDATION

2.1 Dyslexia Across Different Languages

Many studies have argued that phonological deficits are the primary source of the reading difficulties found in dyslexia [2, 22]. This is also consistent with the view across research from different perspectives and with different languages, that dyslexia is a multifactor disability, where phonology is central in most cases [31]. The relationship between phonological processing skills and reading skills appear to differ based on the orthographic transparency of the language. Hence, dyslexia can be considered as a language-dependent learning difficulty because it depends upon the reading process within a specific language. This reading process appears to vary between different languages depending mainly on the characteristics of the orthography and the linguistic structure of the language being used.

Despite the variation in language orthographies (for instance, either shallow (transparent) or deep (non-transparent)) examples of dyslexia appear in all languages [13]. Elbeheri et al. [15] describe how the differences in the orthography of a language influences the types and severity of the spelling, reading and phonological problems that are apparent in people with dyslexia. For example, according to Spencer [36], readers in languages with shallow orthographies, such as Turkish, Italian, Spanish, German and Greek, face fewer difficulties in reading than readers in languages with deep orthographies such as Dutch, English and French. This is consistent with the work of Landerl et al. [26] who argue that English speakers with dyslexia suffer from much more severe reading difficulties than German speakers. On the other hand, in languages with both shallow and deep orthography, such as Arabic and Hebrew, these problems depend upon the type of orthography that is being used (for instance, in Arabic there are alternative orthographies that include short vowels and others where they are omitted) [13]. In the case of Arabic, problems can occur when short vowels are omitted from texts because this results in significant ambiguity when they are processed [1].

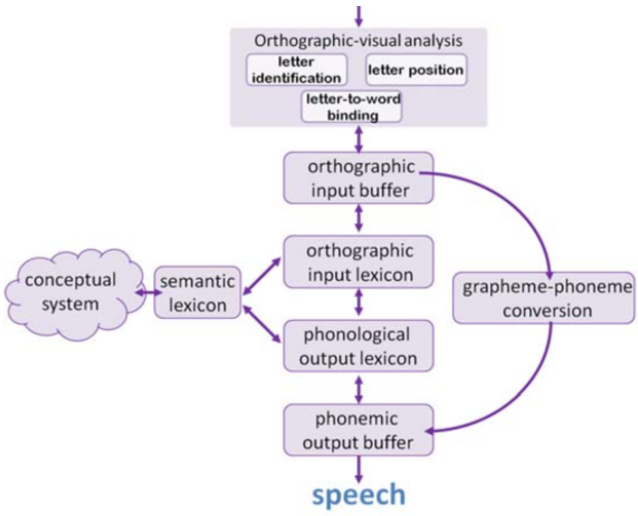

Figure 1: The dual-route theory of reading aloud [16].

2.2 Types of Developmental Dyslexia

The first researcher who suggested that there are various types of developmental dyslexia was Helmer Myklebust in 1965 [16]. Later, these types of dyslexia were interpreted according to the dual route theory of reading aloud that defines the various components of the reading process that every reader must master. This is shown in Figure 1. At a high level, in this model there are two alternative reading routes: the lexical route and the non-lexical route. The lexical route is used when a reader can identify a word by recognition alone, without accessing the phonological knowledge or having to perform a detailed analysis [20]. Alternatively, the non-lexical route first identifies letters, builds a grapheme and then maps these to phonemes which can be read aloud [20]. This model is currently used by many different researchers [17], because it predicts the most common types of dyslexia [16].

According to the dual route theory of reading, ten types of developmental dyslexia have been identified, each one resulting from an impairment in different components of the reading process [16, 17]. Some of these types of dyslexia have been reported in various languages, including Hebrew, Turkish, Arabic, Italian and English [16, 17]. Arabic dyslexia is targeted in this study because there is a paucity of research which has targeted this, despite it being a widely spoken language with a considerable rate of dyslexia [9].

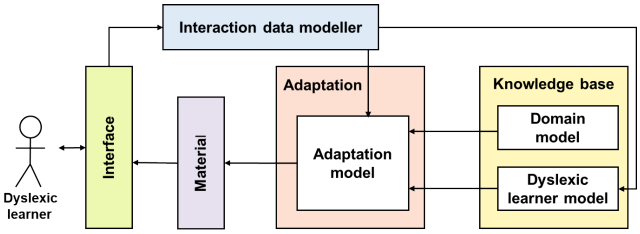

Figure 2: An adaptive e-learning framework for dyslexia.

Among these various types of dyslexia, letter position dyslexia and vowel letter dyslexia have been targeted in this study due to their prevalence in Arabic [17].

Letter position dyslexia is characterised by difficulty in encoding the order of letters within a word. Its main characteristics being the transposition of letters within a word, especially middle letters, while keeping the first and last letters in their proper positions [18]. For example, the word "cloud" might be read as "could".

Individuals with vowel letter dyslexia usually omit, transpose, substitute or add vowel letters [17]. For example, the word "bit" can be read as "but", "bat" or "boat". Knowing the characteristics of these dyslexia types is crucial for diagnosing them, and consequently for determining the appropriate approach to treatment and teaching [16].

Therefore, using just one teaching approach for all forms of dyslexia is not appropriate. This highlights the importance of adaptation based upon dyslexia type in student learning.

3 ADAPTATION BASED ON DYSLEXIA TYPE

Adaptation in e-learning systems means tailoring the learning environment to meet differences between students [28]. The main objectives of adaptation is to increase the students' learning outcome, to improve their experience over time [29] and to enhance user satisfaction [14]. Therefore, the design of e-learning content should meet the different needs of different students and their different expectations. Suitable e-learning material will contribute to more engaged and motivated students [33], which is a crucial contributor to students' satisfaction.

In Figure 2 we present an abstract view of the adaptive system used in this work. This is based upon the model presented in [5]. It includes three main components: the domain model, the adaptation model and the dyslexic learner model. The important difference is that the dyslexic learner model is augmented to include the diagnosis of the dyslexia type of the individual learner which, here, is either letter position dyslexia or vowel letter dyslexia. In this work, this model is instantiated by using a reliable, offline diagnostic tool (see subsection 4.1). This is important in order to be able to build a sound evaluation of the effectiveness of the adaptation. In the future, it would be possible to incorporate online diagnosis.

The domain model represents learning material in a way that facilitates a specific approach to adaptivity based on dyslexia type when using the system. An example of the domain model is presented in Figure 3. The system presents the reading course structure as a hierarchical network at five levels. Level one represents the course "reading". In this context, a course is made up of several concepts,

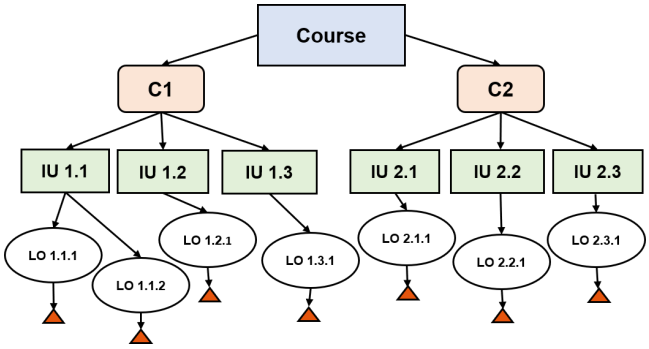

Figure 3: An example of the reading course structure (C=concept, IU=instructional unit, LO=learning object).

Figure 4: A Screenshot of the interface.

which are addressed in level two. Each concept is made up of a series of instructional units, or "IUs", at level three. Each IU deals with one particular element of the concept and consists of a number of learning objects, or "LOs", at level four. These are annotated based on dyslexia type (either letter position dyslexia or vowel letter dyslexia). Level five contains teaching materials for each LO. The adaptation model considers both the domain model and dyslexic learner model to adapt the relevant material (for example, by constructing personalized learning paths based on a learner's characteristics).

There are two other components included in the adaptive e-learning framework, which are the interaction data modeller and the interface. The interaction data modeller is responsible for monitoring interactions between the learner and the system and feeding into both the adaptation model and the dyslexic learner model to update. The interface facilitates the communication between the student and the system. In Figure 4 we show an example of the interface with which the child would interact. In the work presented here we focus on a system for teaching Arabic to students with dyslexia who are native Arabic speakers. Therefore all teaching materials and the user interface are designed for these users. Different word reading exercises are implemented in the system. As shown in Figure 4, the word is displayed on the screen, the student can listen to the word being spoken and then attempts to read it. This helps them

to practice their reading skill. They then choose the corresponding picture as an answer.

4 EVALUATION

A controlled experiment was conducted with Arabic students with dyslexia in elementary schools to evaluate the proposed approach in terms of satisfaction of students with dyslexia. Two experimental conditions were put forward. The first condition, the matched group, consisted of students with dyslexia who used an adaptive version of the e-learning system. This matches learning material according to dyslexia type. The second condition, the mismatched group, consisted of students with dyslexia who used a non-adaptive version of the e-learning system that does not match learning material according to dyslexia type. Apart from the detailed learning content, the two versions were identical in every respect. What changes is the content of the learning material. All learning materials were in Arabic and were designed to teach the reading of Arabic words.

4.1 Data Collection

Several data collection instruments were used in this experiment: a diagnostic test, 3 isomorphic performance tests (a pre-test, an immediate post-test and a delayed post-test) and a satisfaction test. The dyslexia type was diagnosed according to diagnostic tests based on the reliable and standardized diagnostic tests approved by the Ministry of Education in the Kingdom of Saudi Arabia (KSA) for special needs students [12].

Pre- and post-tests were used to assess students' level of reading performance. They include ten words from the curriculum. These tests have been validated by special education experts. Every student was asked to read aloud a set of words to assess their level of reading performance. The pre-test is used to assess each learner's prior level of performance and to balance the experimental conditions. The immediate post-test assesses the student's performance at the end of the course. The delayed post-test was performed several weeks later to assess whether the learning is persistent.

The satisfaction of students with dyslexia was measured by a validated and reliable tool, the E-Learner Satisfaction (ELS) questionnaire [38]. ELS measures overall satisfaction and satisfaction related to different components, such as system interface, system personalization and learning content [38]. These three components are considered in this study and assessed through ten questions measured on a 5-point Likert scale. Since the target users are young children, the original 7-point Likert scale that ranges from "strongly disagree" to "strongly agree" is not appropriate due to the difficulty children have in its understanding and interpretation [32]. An alternative method is the Smileyometer [32], a widely-used instrument in academia and industry, as shown in Figure 5. It uses pictorial representations with a 5-point Likert scale that enables children to identify their opinions and feelings by ticking one face [32]. Therefore we used this version of the ELS, adapted to a 5-point scale using the Smileyometer.

4.2 Experimental Procedure

This study was subject to ethical approval by the institution. Before the students participated in this study, permission was obtained from their parents/guardians and schools. All students with dyslexia were selected from schools in KSA. Their demographic information, such as grade and age, was collected, and the dyslexia type, either letter position dyslexia or vowel letter dyslexia, was identified through the diagnostic tests. Students with other or multiple dyslexia types were not included in the study. After that, the pre-test was conducted to determine students' prior reading performance. Then, the students were randomly divided into two balanced groups: the matched group and the mismatched group. The two groups were balanced by age, prior reading level and dyslexia type.

Figure 5: The Smileyometer [32].

The experiment was conducted in a quiet room within the student's school. Neither the student nor the experimenter was aware of the experimental condition to which the student had been allocated. The study was first introduced by the experimenter who then attended every session to make an observational record. Students worked individually with the system. There were a total of eight sessions: two sessions per student per week. Each session consisted of a reading exercise with 10 words per session (as shown in Figure 4). Each session had a duration of approximately 30 minutes and the total duration of the study was one month. Each session covered a different part of the curriculum. At the end of the learning process (after the final session), the students completed the ELS questionnaire and the immediate post-test, to measure the immediate reading performance. A few weeks later, the students completed the delayed post-test to measure the delayed reading performance.

4.2.1 Participants. In total, 40 students with dyslexia, from Grade 2 to Grade 6, participated in this experiment (mean age=8.93 years). All students were female and had already been diagnosed as students with dyslexia. Due to the culture constraints in KSA, it was only possible to have access to female subjects. This also has an advantage of reducing variances between subjects.

All subjects were native Arabic speakers. Twenty students were assigned to the matched group, and 20 students were assigned to the mismatched group. Forty-seven per cent of students were diagnosed with letter position dyslexia and 53 per cent with vowel letter dyslexia. All of the students completed the experiment.

5 RESULTS

Based on the analysis of the students' satisfaction, as shown in Table 1, the matched group (Mean=4.90, SD=0.18, Median=5) had a larger mean satisfaction score than the mismatched group (Mean=4.68, SD=0.38, Median=4.75), indicating that there was a positive effect on the satisfaction of students when learning material was adapted to their dyslexia type. The two versions of the e-learning system were identical except for the lesson content. The only difference was that, in the adaptive condition, the learning material was adapted to the student's dyslexia type.

Table 1: Satisfaction scores of students with dyslexia.

ELS component	Matched group		Mismatched group	
	Mean	SD	Mean	SD
Learning content	4.88	0.33	4.53	0.99
System interface	4.91	0.29	4.77	0.50
System personalization	4.90	0.21	4.68	0.65
General satisfaction	4.90	0.18	4.68	0.38

There was a statistically significant difference between the overall satisfaction in the two conditions (Independent sample Mann-Whitney U test (U= 277.5, p=0.023)). There was also a statistically significant difference in the satisfaction scores between the two conditions for each of the three components of the ELS.
This suggests that students are aware of when a lesson is more suited to their needs and that this affects their perception of the quality of the course. Further, this perception of suitability affects their attitude not just to their assessment of the learning content component but also to other aspects of the system. The System Interface and the System Personalisation were identical between the two conditions and yet these were also rated more highly in the adaptive condition.

6 CONCLUSION AND FUTURE WORK

The work presented in this paper investigated the satisfaction of students with dyslexia in an adaptive e-learning system. Adaption of e-learning to the dyslexia type of a students is an under-researched area. This is true for dyslexia across all languages and cultures.
Both theoretical models of dyslexia and classroom practice suggest that there are these different types of dyslexia and that the teaching that students receive should vary according to this type. The approach to adaptation presented in this work involves personalizing the learning material according to this significant characteristic of dyslexia: dyslexia type. The approach was evaluated by a controlled experimental study conducted with 40 Arabic students with dyslexia in elementary schools in KSA.
Our study's results follow the argumentation of Kangas et al. [21] that there is a strong association between students' motivation and satisfaction, where satisfaction is influenced by the provided learning contents. This is in line with earlier literature [23, 25]. The results show a significant increase in student satisfaction when using the adaptive e-learning system (where learning material is matched to their dyslexia type). Therefore, this paper contributes to recent research by supporting the significance of adaptive e-learning systems based on dyslexia type in terms of the satisfaction of these students. There was also a statistically significant effect on the immediate and delayed learning gain of these students. However, these results will be reported elsewhere.
Student satisfaction is an important metric for assessing the effectiveness of e-learning systems [19]. It has a value in its own right but it also has other implications. If students perceive a system as being useful (for example, they are satisfied with it), then this can positively affect their motivation and their engagement with their learning. These are both widely argued to improve learning.
Further, it is a useful way to assess how well the learning matches the students' needs. Whilst they may not be able to explicitly assess this match, they are, at least subconsciously, aware of it and this will even be reflected in their assessment of aspects of the system that do not change between conditions [4].
Whether these results can be generalised to other languages, cultures and age groups, or to other learning domains, is unclear and will require further investigation. The structure of the Arabic language and its orthography are different from, for instance, those of English. Therefore, dyslexia in Arabic is manifested in different ways from dyslexia in English [35]. Several types of dyslexia have been identified and reported for Arabic. These include: letter position dyslexia, visual dyslexia, vowel letter dyslexia, attentional dyslexia, neglect dyslexia, surface dyslexia, and deep dyslexia [17]. Some types of dyslexia have been also detected in other languages, such as English, Hebrew and Turkish, while some of them have not yet reported [16].
In this study, we mainly focused on the two most common types of dyslexia in Arabic. These are letter position dyslexia and vowel letter dyslexia. Letter position dyslexia has also been reported for English, Italian, Hebrew and Turkish [16], while vowel letter dyslexia has been detected in Hebrew, Turkish and Italian [16]. We believe, in general, that matching the needs of students affects their satisfaction and, therefore, their motivation, engagement and learning. Therefore, in the future we will investigate whether this study's results can be generalized to other types of dyslexia in Arabic and also whether they can be generalized across different languages. Moreover, whether these results can be generalised to other cultures, to male students and to other age groups, or to other learning domains, may be likely but is not answered by our study and will require further investigation.
This work is part of an investigation into dyslexia type-based adaptive e-learning system and satisfaction of students with dyslexia. The work is being extended to include other characteristics of students with dyslexia, in addition to dyslexia type. These will include their current skills and other characteristics. A further experimental evaluation that measures satisfaction of students with dyslexia, their perception of the usability of the system and, most importantly, the effectiveness of the learning is currently being undertaken.

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