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Communication Technology for Users with Specific Learning Disabilities

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Abstract

In this paper we focus on the potential benefits of the use of Information and Communication Technology (ICT) to facilitate and promote learning for students with specific learning disabilities. This work reports the most representative studies about the inclusion of ICT applications for the target users and aims to derive practical guidelines on this aspect by exploring the experience of Arabic readers with and without dyslexia when using online text which is based on a user study with a group of 32 users (12 users with dyslexia). The data collected analyses spelling errors faced by Arabic learners. The comparison between the experience of learners with and without dyslexia has yielded insights into the need to consider features of the Arabic language that account for the unique needs of users with specific learning disabilities.

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1. Introduction

Recently, there has been an increase in the use of Information and Communication Technologies (ICT) in the field of education. A significant amount of research^{1,2,3} has proven that ICT use plays an important role in supporting students especially those with specific learning disabilities. Dyslexia is one of the most common learning disability that affects the educational development of a student. It is a neurologically based learning disability characterized by difficulties in reading and writing activities. According to⁴, dyslexia is a specific

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disorder that involves a severe impairment in reading ability, which affects and disrupts a person's language development and functioning.

However, ICT use may have positive effects on learners with learning difficulties. Affirmed to² ICT can facilitate access to students by increasing their motivation, fostering self-competition, enhancing their confidence and self-esteem. Regarded to⁵ students with dyslexia typically have a low self-esteem, and low expectations of their academic opportunities. It is possible to see that ICT is a key tool in the support of dyslexic students. It may facilitate learning and reduce the difficulties recognizing or confusing between words and meaning. ICT use has probably strong positives effects on learning it tends to increase student's confidence, motivation and self-esteem. Particularly designed applications can stimulate student's interest and overcome their learning difficulties. As claimed by⁶ the use of ICT has a valuable role in providing opportunities for the target users to participate more fully in education. It tends to improve and develop interactive experiences that can motivate the users.

Hence, dyslexia may manifest itself differently for speakers of different languages and most of the research on developmental dyslexia comes from English-speaking countries. Therefore, dyslexia in English is different from dyslexia in Arabic. As stated by⁷ the manifestations of dyslexia differs across different languages, and it is not language independent. However, Arabic is the largest member of the Semitic language family. It is written in an alphabetic system consisting of 28 letters to represents 34 phonemes, 25 consonants and three vowels considered as a long vowels (a, i, u) (أ، و، ي). However, the short vowels are usually not represented in the orthography, except for beginning readers vowels are marked by vocalization diacritics. Additionally, in Arabic there are no upper or lower case variations. Arabic language involves the use of diacritics that appear on top or below letters to represent short vowels, gemination, case, and silence. Arabic is considered as a bi-directional language since the script is read and written from right to left, whilst numerals written from left to right. Thus, Arabic is considered as a transparent and non-transparent orthography language. According to⁸, Arabic is stressed differently from English, since stress in Arabic is a morphological feature that depends on the syllable structure of the Arabic words. Hence, Arabic readers need to gain morphological knowledge to be able to express the position of the required Arabic stress. Consequently, Arabic is a widely spoken language, it may have a considerable rate of dyslexic readers. Unfortunately, a review of the literature about Arabic reveals that few studies have been conducted to explore dyslexia in this language, and most of these studies focus on the difficulties and complexity of Arabic.

Although there exists a variety of research within the areas of dyslexia, ICT use and assistive technology there still seems to be a research gap. This study, thus took the initiative to explore the learning experiences of Arabic readers with and without dyslexia in a single study to derive practical guidelines for inclusive dyslexia-friendly virtual environment. Therefore, this paper presents the following two main contributions:

- The inclusion of dyslexics Arabic readers in Information and Communication Technologies use.
- A set of practical guidelines based on the analysis of dyslexics spelling errors.

The researches provide the following hypothesis statement (H1): Dyslexic students made significantly more spelling errors in reading Arabic online text compared to non-dyslexic students.

The rest of the paper is organized as follows. Section 2 presents the related work. Section3 addresses the methodology of research used. Section 4 discusses the findings of the previous section and introduces practical guidelines for Arabic dyslexic users. Section 5 discusses conclusion and future works.

2. Related work

Recently, various programs for tablets and smartphones have been available for supporting students with learning difficulties. There exists a variety of research within the areas of the inclusion of users with learning difficulties in ICT use. Among the studies there is a paper presented by², which introduced a mobile application called *Easylexia* for children with special learning needs, that provides a learning environment which fosters learning and helps children with their learning difficulties by improving some of their elementary skills, such as language and mathematical abilities. However, its effectiveness has not been demonstrated, thus at this stage this mobile application cannot be conclusive.

Similar works, *MyLexics* is an interactive multimedia program developed by⁹ that supports children with learning disabilities. It is a courseware that integrates all multimedia elements that reinforces interactive and self-learning environment for dyslexic students and targeted to strengthen alphabetic, syllables and words through reading and writing in Malay language. *MyLexics* content has been structured as building-up process, where the children learn the individual alphabets by combining the alphabets to other syllables, and then they add the combined syllables to other syllables and form words. The main advantage of *MyLexics* that it was developed using Dual Coding theory¹⁰ and Scaffolding teaching strategy¹¹. The concept of the dual coding theory is that learners have separate channels for processing visual/pictorial and auditory/verbal representations. The theory assumes that there are two cognitive subsystems, which could lead a learner to expand on learned material; one specialized for verbal association and the other specialized for the representation and processing of nonverbal objects/events. While, the Scaffolding teaching strategy supports the thought processes of the student and promote a deeper level of learning. Those strategies could enhance recall and recognition and help to retain information in the memory. Also, they could reduce the negative emotions and self-perceptions that children may experience when they discouraged when attempting a difficult task. Similar studies¹² integrate the use of user modelling technique for dyslexic individuals in virtual learning environments and assume that user modelling approach provides assistive and accurate adaptivity for the target users.

Related studies should be mentioned as they too describe research in the field of ICT use within the context of including users with specific learning disabilities. Assistive Mobile Applications for dyslexia presented by¹³ is a prototype of a mobile application aimed at re-educating and monitoring the learning process. The program focuses on the Portuguese language and includes a set of different exercises aiming at identifying; the beginning of words; rhymes (the end of words); sequences of letters in the words and syllabic structure of words. The main characteristic of this assistive application is the implementation of the multisensory re-education approach, which involves the use of visual, auditory, and tactile pathways simultaneously so as to enhance memory and written language learning. The outcomes show that the proposed program allows dyslexics to improve multisensory perception, constituting an added value facilitator of adaptiveness and learning. Additionally, *Dyslexia Baca*¹⁴ is a mobile application specifically developed to help dyslexic children to recognize and distinguish letters in a Malay language learning model. The application uses an interactive method by using a colorful balloon to retain the student's attention and give a clap sound as a complimentary of the success selection. *Dyslexia Baca* adopts the multisensory approach and the Learning Ecosystem model that takes into consideration the learner styles and the learner needs. The development of this application is based on ADDIE model. However, the evaluation provides only a feedback from the perspective of expert not from the students with dyslexia.

Further, *Dysegxia*³ is a game application with pedagogical exercises to support children with dyslexia to improve their spelling skills. It includes exercises in Spanish and English. *Dysegxia* seems to differ from other models for two main reasons: firstly, it contains reinforcement word exercises inspired by pedagogical books. Secondly, it is based on the analysis of errors written by people with dyslexia. However, the primary evaluation used the think aloud technique with a small sample that only covers seven children with dyslexia. Furthermore, the design of word exercises method used in *Dysegxia* was also reported in another work by¹⁵, that presents the method of design reinforcement word exercises to support children with dyslexia on the basis of the analysis of errors written by people with dyslexia in combination with linguistic, pedagogic and cognitive criteria. The method includes six steps: definition of the exercise type, word selection, word modification, distractor selection, difficulty levels, and text layout. However, the longitudinal evaluation has not yet been reported to study its long-term effect on overcoming dyslexia.

Other related work can be found in the area of ICT and learning disabilities such as the work of¹⁶ about *AGENT-DYSL* approach, which is an adaptive reading assistance for students with dyslexia. The main objective of this study is to combine speech recognition, affective state recognition via image recognition, and error type profiling to promote the development of reading skills then to provide personalized support by adapting to the environmental needs. The characteristics of this project are speech processing to detect anomalies in the reading performances and image processing that captures attention patterns, emotional state and inputs from teachers who encode their knowledge of this individual learner. However, the main disadvantages of the software were that it was not tailored to the needs of adults and was limited to assisting children with reading dyslexia, not any other dyslexia difficulties. Moreover, an adaptive mobile learning system was developed by¹⁵ based on the analysis of dyslexic students' learning style preferences. The model aims to help dyslexics to improve some of their fundamental skills such as reading, writing, comprehension, Arabic orthography, short-term memory and

concentration. The application is developed in Arabic language and it includes the following tasks with specific aims and predefined pedagogical objectives: Recognizing letters; the aim is to support learners' reading skills. Structure of words; the aim is to improve learners' writing skills, and identifying letter/word shape; the aim is to improve learners' short term memory and concentration. The system adopted the Cognitive Theory of Multimedia Learning¹⁸ and the constructivism pedagogical approach for learning¹⁹. The outcomes provide that digital technologies positively impact dyslexic students learning process and an increase in motivation and achievement was observed. However, the preliminary evaluation covers only a short period of time usage.

3. Proposed approach

3.1. Participants

Native speakers of Arabic were participated in this study. The sample (n=32) is split into two groups, experimental and age matched control group. The experimental group consists of 12 students their ages were between 8 and 12 years (mean=10.5, SD=1.31). They had been diagnosed with dyslexia (5 children with phonological dyslexia and 7 children with surface dyslexia). They were selected from Speech-Language Pathology service-Health, El Jadida Morocco by the president of the Speech-Language Pathology service-Health center. The control group consists of equal numbers of boys and girls, 20 students 10 girls and 10 boys their ages were between 8 and 13 years (mean=9.85, SD=1.56). They were selected from primary schools in El Jadida city. According to their self-report they had no prior diagnosis of any learning disabilities. Table 1 presents the distribution of participants in terms of gender and group

Table 1. Distribution of participants in terms of gender and group.

	Experimental group (Dyslexia)	Age-matched control group (No SLDs) ^a	Total
Girl (n)	02	10	12
Boy (n)	10	10	20
Total (n)	12	20	32

^a No Specific Learning Disabilities

3.2. Instruments and procedure

During the visit, we explained the background and the component of the study to the directors and the teachers, and also to the participants. All the participants were asked to read aloud the online text while the session was recorded. The electronic text contains about 80 words and was displayed on tablet full screen. The text was divided into four passages.

3.3. Statistical Analysis

Statistical analysis was performed using R software, version (3.3.1), with the standard condition of $p < 0.05$ for significant results. We used the Shapiro-Wilk test for checking if data fit a normal distribution, Durbin Watson for testing independence and Bartlett test to check for homogeneity. Since the data is normally distributed and does not fit the assumption of equal variances, we used Welch t-test to compare the means of the two groups. We include the mean, the standard deviation and the median for all our measures. Table 2 presents Mean, the standard division (SD) and median of total of spelling errors for experimental group and match aged control group.

Table 2. Mean, Standard Deviation (SD) and median of types of spelling errors of experimental and age-matched control groups

	Experimental group (Dyslexia)			Age-matched control group (No SLDs)		
	Mean	SD	Median	Mean	SD	Median
Long vowel	6.33	3.55	5.5	0.10	0.30	0.0
Short vowel	5.25	2.76	5.5	1.85	1.59	1.5
Transposition	2.16	3.32	0.5	0.45	0.82	0.0
Letter additions	2.85	2.02	2.0	0.25	0.44	0.0
Omitting letters	5.33	3.77	5.0	0.60	0.99	0.0
Add words	1.08	1.67	0.0	0.20	0.69	0.0
Syntactical rules	6.0	2.66	6.0	1.05	1.14	1.0
Total of spelling errors	28.75	11.56	28.50	4.50	3.54	3.5

4. Obtained results and discussion

Shapiro-Wilk tests showed that the data was normally distributed, Durbin Watson test showed a no autocorrelation. However, Bartlett test revealed that the variances are not equal.

To examine the H1 research hypothesis, Welch t-test was applied in order to compare the total of spelling errors by groups. Significant results were found between the scores of spelling errors of dyslexic and non-dyslexic Arabic students in reading online text. At 95% confidence level, there is a statistically significant mean difference $t(12.185) = 7.0391$, $p\text{-value} < .00001$ in total of spelling errors between experimental group and age matched control group. Results show that dyslexics tend to have a higher score of spelling errors than non-dyslexics in reading Arabic online text. Figure 1 presents box plot by total of spelling errors of dyslexic and non-dyslexic Arabic readers. Table 3 demonstrates presentation of t-test results for total of spelling errors by groups.

Table 3. Results of t-test and Descriptive Statistics for total of spelling errors by groups

	Experimental group (Dyslexia)			Age-matched control group (No SLDs)			95% CI for Mean Difference	t	df	P
	N	Mean	SD	N	Mean	SD				
Total of spelling errors	12	28.83	11.69	20	4.45	3.48	16.84, 31.91	7.03	12.18	< 00001

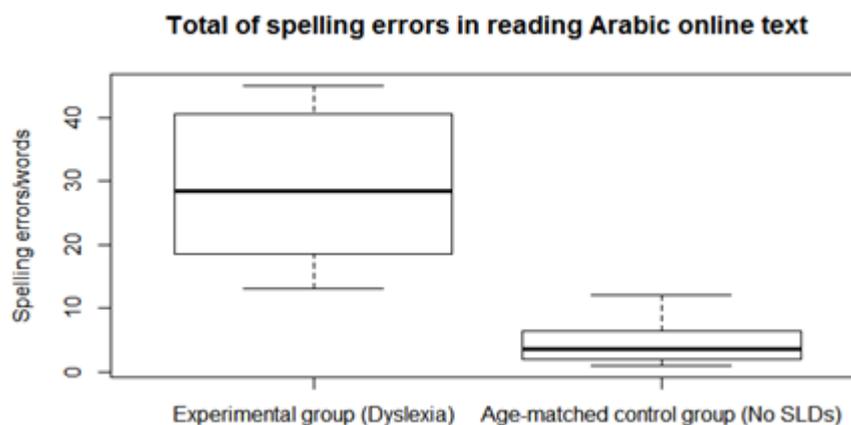


Fig. 1. Total of spelling errors of dyslexic and non-dyslexic Arabic readers.

However, Arabic spelling is hard not only for dyslexic children but also for non-dyslexic children. Learning to read in Arabic requires the connection between the graphemes and their sounds then the application of grammatical rules. Arabic is considered as an irregular language, many factors of the linguistic features of the language may promote the manifestation of dyslexia in Arabic, for instance:

- The use of dots to differentiate scripts.
- The use of diacritics marks or short vowels that contribute phonologically to the Arabic script and to the grammatical rules.
- The shapes of Arabic scripts that change depending on the position within the word initial, medial or final.
- The way connecting letters to create words.
- Difficulty of distinguishing the phonological similarity letters and the similar orthographic between different graphemes.

The Findings of this study indicate that young Arabic readers face many difficulties in reading online text. However, Arabic spelling is hard for both group; dyslexic children and non-dyslexics. The results reveal that the factors which most affected reading accuracy are phonetic and semi-phonetic errors that were more prevalent in Arabic dyslexic readers followed by omitting letters and syntactical rules. Hence, the results indicate high accuracy rates among dyslexic readers. Therefore, it is important to consider Arabic features including morphological, syntactical and semantic structures in designing Arabic assistive tools. This awareness could be helpful for designers to support the design and evaluation of Arabic training for users with reading disabilities.

Until now, the majority of research was largely confined on the English language. For this reason, we aim to develop an understanding of manifestations of dyslexia in Arabic language so as to address some practical guidelines on dyslexia in Arabic for accessibility issues related to online text presentation. The design guidelines tend to follow the Arabic language characteristics that have a low degree of similarity with English language, in that it cannot be applied directly in Arabic communication technologies applications especially for the target users. The proposed design guidelines cover four main areas; phonological processing skills, cognitive processing, orthographical similarity and visual ability. Those areas are represented as follow:

- Offer to dyslexic readers the possibility to hide or show diacritics (short vowels). However, it is important to consider automatic diacritization in digital Arabic content, in that users can control the appearance of diacritics in online text.
- Present long vowels in deferent size or in deferent colors, by using color coding methods, in that the users can dustings long vowels from other letters.
- Obtained results from analysis of spelling errors for dyslexic and non-dyslexic, showed that users with dyslexia confront many difficulties and confusions during reading activity. They are not able to differentiate orthographic similar-looking letters as (د, دل) and especially those with dots such as (ب, ت, ث, ن, ي), (ج, ح, ح), (غ, ع). Also, phonological similarity letters as (ص, ض), (س, ص) and (ص, ط). Therefore, to differentiate similar letters, especially those with dots we recommend the use of color coding methods to represent the dots and their position.
- Among spelling errors faced by Arabic dyslexic readers are letter omissions, particularly the end of the word, for this reason we recommend to present in different color or size the end of the word or the additional patterns that may come as prefixes or suffixes.
- In Arabic, too small font size could be one of the key problems experienced by users with dyslexia. However, Arabic script is usually presented in larger sizes than English. Also, the fact that Arabic calligraphy is developed as an art that is considered as a decorative element, which may contribute to over load the dyslexic cognitive working memory. Hence, it is important to offer the possibility for dyslexic readers to adjust the electronical text size and the font types so as to create texts that are easy to read.
- Using short sentences which are easier to read and comprehend are recommended.
- In this study, we observed that spacing between letters and words is a problem in the presentation of Arabic online text, particularly when functional words or lexicon prepositions are presented in the text such as (في, من, مع, الى, عن), dyslexics read it as one single word. For instance, (في عطلة الصيف) was spelled (فيعطلة الصيف). This might add to the difficulties dyslexics face in the visual processing of text. Hence it is recommended

that spacing between letters and words be increased.

- In the virtual environment, it is important to focus on using interaction of a variety of auditory and visual approaches to develop phonological skills and to enhance reading activities. The multisensory approach is recommended.
- During the study, we noticed hesitations and pauses in reading online text, especially among dyslexic readers. Hence, we recommend the use of spoken encouraging feedback to increase learner's confidence and self-esteem.

5. Conclusion and future works

Information and Communication Technologies may have barriers that impact the experience of dyslexic users in the virtual learning environments. Especially in the Arabic world there is still a great lack of integrated tools that provides Arabic dyslexic users with the appropriate set of adjustments according to the diversity of user needs. In order to make their access easier, dyslexic users probably need tools that provide assistance when interacting with electronic systems.

This paper presents practical guidelines for promoting accessibility of digital Arabic content for students with specific learning disabilities, derived from the target user experience. This investigation was introduced into this rare research area in order to prove information in terms of whether or not further research should be introduced into the field of Arabic and dyslexia. These guidelines need to be further supported by experimental research and tested with dyslexic users of Arabic content. In our ongoing work, this current approach will be developed in assistive learning tools and we will study its effectiveness on learning performances and evaluate its usability on users with dyslexia.

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