The Impact on Reading Performance and Learner Satisfaction & Behaviour, of Matching E-Training Material to Dyslexia Type

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Dyslexia is a universal reading difficulty that can be found everywhere regardless of a person’s ethnicity or race. Its manifestation is language-dependent and is affected by the language’s structure and orthography. There is a lack of research into Arabic dyslexia and especially into the benefits of adaptive learning in this domain. This study aims to understand the impact on learners’ reading performance, satisfaction and behaviour when matching e-training material to a learner’s attributes. The focus is on learners with short vowel dyslexia (SVD). The study was undertaken with 22 female primary school children in Saudi Arabia, who were all native Arabic speakers. An e-training system DysTypeTrain2 was designed and developed to support the study. It was found that both the reading performance and satisfaction of learners with dyslexia were improved in both experimental conditions (SVD group and vowel dyslexia (VD) group), regardless of their dyslexia type, indicating that the system was effective and the learning process was enhanced.

Arabic, Dyslexia Types, E-learning, Matching, Reading Performance, Learner Satisfaction, Adaptation

1. INTRODUCTION

Reading is the gateway to learning. There are different classes of readers; one class may read fluently, without errors and will understand what they read. Whereas another class may face difficulty with reading or comprehension, which negatively affects all of their learning and their lives in general. Such readers are diagnosed with dyslexia. Dyslexia is a universal reading difficulty that can affect any individual regardless of their background and language. The term is derived from Greek: composed of the prefix “impaired” and the base “word”, resulting in “difficulty in words” (Critchley 1968; Berninger et al. 2008; Alsobhi, Khan and Rahanu 2014). Around 15-20 percent of the worldwide population has a learning difficulty, of which 70-80 percent have dyslexia (Alghabban, Salama and Altalhi 2017). Individuals with dyslexia face different difficulties; some are related to reading while others to spelling, maths and writing. Each individual is different in their difficulties. So, they should be treated individually according to their needs. Unfortunately, most research treats them all in the same way.

The work presented in this study aims to provide learners with an e-training opportunity that considers their needs and symptoms – and to evaluate its effectiveness. Different approaches have been taken to deeply understand dyslexia and to classify it into different types that reflect its causes and symptoms. Ingram’s classification is one attempt that classified dyslexia based on the ‘symptoms’ (Alsobhi, Khan and Rahanu 2014). Another approach has classified dyslexia based on the type of deficit within the dual-route model for single word reading (Friedmann and Coltheart 2016). This model helps to predict the different ‘symptoms’ of different types of dyslexia. It has proved effective and is widely used (Annett 1996). This is the classification that is adopted by this study. This study investigates the impact of matching the e-training material to learners with short vowel dyslexia (SVD) by assessing their reading performance, satisfaction and behaviour. The remainder of this paper is organized as follows. Section two presents the background upon which the study is built. Section three presents the experimental design of the research, while section four presents and analyses the data collected and.
discusses these results. Finally, section five draws some conclusions and points to future work.

2. BACKGROUND

This section covers the theoretical foundation behind this study, the definition of dyslexia and its symptoms, dyslexia in Arabic and its classification into types, and also other related work upon which this study builds.

2.1. Dyslexia Definition

Dyslexia has been defined by the British Dyslexia Association (BDA) (Singleton 2009) as:

Dyslexia is a learning difficulty that primarily affects the skills involved in accurate and fluent word reading and spelling. Characteristic features of dyslexia are difficulties in phonological awareness, verbal memory and verbal processing speed. Dyslexia occurs across the range of intellectual abilities. It is best thought of as a continuum, not a distinct category, and there are no clear cut-off points. Co-occurring difficulties may be seen in aspects of language, motor co-ordination, mental calculation, concentration and personal organisation, but these are not, by themselves, markers of dyslexia. A good indication of the severity and persistence of dyslexic difficulties can be gained by examining how the individual responds or has responded to well-founded intervention.

Dyslexia has various symptoms such as; (1) reading problems (2) writing & spelling problems (3) social & behavioural difficulties and (4) short-term memory problems (Friedmann and Coltheart 2016; Critchley 1968; Walker 2014). Dyslexia is also affected by the structure and orthography of a language. Arabic is targeted in this study primarily because of a lack of research into Arabic dyslexia itself and also into how best to support Arabic learners with dyslexia. More details are given below.

2.2. Dyslexia & Arabic

Since dyslexia is affected by the language, so the language’s orthography and structure have a large impact on the symptoms. Unfortunately, few studies have explored dyslexia in Arabic, so this study targets native Arabic speaking learners with dyslexia. Arabic is the fifth most spoken language. It is spoken as a first language by over 200 million people and as a second language by millions of Muslims (Mahfoudhi, Everatt and Elbeheri 2011). The Arabic orthography is different from that of English. For instance:

(i) Arabic uses a cursive script where the letters are joined together to form a word or sub-word.

(ii) Arabic uses dots to distinguish between similarly shaped letters.

(iii) Arabic uses different letter forms depending on a letter’s position within a word.

(iv) Arabic can use non-vowelized text (Elbeheri 2005) which is an Arabic script without diacritics. Reading such a script is a difficult process for beginners and poor readers (Abu-Rabia, Share and Mansour 2003).

2.2.1. Dyslexia Types in Arabic

As mentioned in the “Introduction” section, this study adopted the dyslexia types classification based on the different deficits within the dual-route model for single word reading (Friedmann and Coltheart 2016).

![Figure 1: Dual-route model for single word reading (Friedmann and Coltheart 2016)](image)

The reading process illustrated in Figure 1 can be summarized as (Friedmann and Coltheart 2016):

(i) Identifying the word’s letters, encoding their positions within that word and binding them to that word via the orthographic-visual analysis system.

(ii) Storing the result of the previous stage and decomposing the word via the orthographic input buffer.

(iii) Known words are read quickly and accurately via the lexical-phonological route by passing that word to the orthographic input lexicon:

(1) The phonological output lexicon will write to the phonemic output buffer.
(2) The corresponding entry in the conceptual-semantic system is activated to access the word’s meaning.

(iv) An unknown word is read via the sub-lexical-phonological route by passing that word to the grapheme-to-phoneme conversion component. It then analyses the word into either individual letters or a group of letters (graphemes) that form a single phoneme. Finally, this information is passed to the phonemic output buffer.

The previous stages illustrate the importance of each component of the dual-route model where each one performs an essential task in the reading process. Therefore, a deficit in any component will cause a reading difficulty and thus a type of dyslexia. Dyslexia in Arabic can be classified into seven types based on the deficit in the dual-route model: letter position dyslexia, attentional dyslexia, neglect dyslexia, visual dyslexia, surface dyslexia, vowel dyslexia (VD) and deep dyslexia (Friedmann and Haddad-Hanna 2014).

2.3. Related Work

A few research studies have contributed to the use of non-e-learning systems for Arab individuals with dyslexia. For instance, a study proposed a set of usability features to improve Arabic assistive technologies for individuals with dyslexia (AlDababayh and Jusoh 2018). They applied these features to a prototype which was then evaluated by a special education expert. They showed that the added usability features increased the individual’s assessment of the usability and enhanced their academic achievement level.

Another study conducted by (Benmarrakchi, Kafi and Elhore 2017) proposed a set of design guidelines based on the spelling errors of learners with dyslexia in online text. These guidelines covered four areas: visual ability, phonological processing skills, orthographical similarity and cognitive processing. However, they left the evaluation of these guidelines to later studies.

(AIRowais, Wald and Wills 2014) developed a framework for evaluating Arabic training tools for dyslexia. This was evaluated by experts through interviews and questionnaires. The findings suggested accepting a majority of the framework’s elements. However, some were excluded, others were improved and new ones were added.

Finally, (Al-Abdulkarim et al. 2010) described a number of user involvement issues during the development of standalone interactive learning systems for Arabic dyslexia and dyscalculia. They found that involving SpLD (Specific Learning Difficulty) specialists during the design process was essential. These specialists helped in transferring the domain knowledge efficiently. Table 1 provides an overview of the non-e-learning related work.

Other research studies have contributed to the use of e-learning systems to teach Arab learners with dyslexia. Some of these studies developed adaptive systems based on learner characteristics while others developed non-adaptive ones. In terms of non-adaptive e-learning systems, a majority of studies used the game-based technique with different evaluation methods to design, develop and evaluate these systems for Arabic dyslexia. (Ouherrou et al. 2018) have developed a standalone educational game application to assess the Arabic skills of learners with dyslexia. The application was evaluated by both specialists and children with dyslexia. They found that the educational game was a supportive tool and that the learning process could be enhanced.

Another study by (Al-Ghurair 2019) aimed to enhance the short-term memory of learners with dyslexia using a story theme in a standalone game-based application. They found that most children wanted to have a copy of the application to use at home, due to its attractiveness. Additionally, the children were engaged and satisfied with the interface’s colouring and theme and they enjoyed the application.

In addition, (Al-Rubaian et al. 2014) proposed to develop the phonological processing skills of learners with dyslexia via designing serious games using a Brain-Computer Interface (BCI). The conceptual design of these games was described along with an overview of the software development framework. However, its evaluation was left for later studies.

Likewise, (El Kah and Lakhouaja 2018) contributed an assistive cross-platform game-based system to overcome the reading and writing difficulties of learners with dyslexia and dysgraphia. The effectiveness of the system was evaluated by comparing the learning achievements of children. They found that the system was efficient and improved the learning process.

Furthermore, a study conducted by (Aljojo et al. 2018) aimed to teach Arabic letters for dyslexia. They developed a puzzle game-based system along with eye-tracking and chatbot features. This system was intended to assist the child in correctly pronouncing the Arabic letters using different short vowels. However, the findings were not discussed clearly.

In terms of adaptivity, (Alghabban and Hendley 2020) investigated how personalizing learning material based on dyslexia type affects children’s satisfaction. An adaptive e-learning system was implemented to improve the reading performance of children in elementary schools. The results showed
that children with dyslexia were more engaged with their learning experience when matching the learning content to their dyslexia type. However, the learning performance and effectiveness were not considered in this study. Other research has considered dyslexia learning style as one characteristic in adaptive e-learning systems. For instance, (Benmarrakchi et al. 2017) aimed to identify the relationship between dyslexia and learning styles. They found that the majority of eight learners with dyslexia were activist and visual learners. Then, they developed an adaptive game-based m-learning system taking into account this preferred learning style. The proposed system aimed to enhance the learners’ reading, comprehension, writing, concentration, short-term memory and Arabic orthography. In the end, they observed an increased motivation and achievement. Unfortunately, the evaluation methodology was not presented, and thus it is difficult to assess its effectiveness. Table 2 provides an overview of the e-learning related work. Overall, little research draws upon the theoretical understanding of dyslexia and uses this to drive adaptive learning. Where this has been investigated, the evaluation of its effectiveness is very limited. Therefore, this study seeks to build upon existing research into the causes and effects of dyslexia and understand whether and how this can be used to drive the adaption of learning to improve the learners’ experience.

3. EXPERIMENTAL DESIGN

To understand the impact of matching the training material to learners’ dyslexia type, an e-training system DysTypeTrain2 was developed and used to run a controlled experiment to evaluate the reading performance and learner’s satisfaction & behaviour. This study is complementary to (Al-Dawsari and Hendley 2021; Alghabban, Al-Dawsari and Hendley 2021). It trains learners with dyslexia using eight reading activities where each activity consists of ten training exercises – giving a total of 80. The difficulty of these activities is gradually increasing. As in the DysTypeTrain, it uses the visuospatial/kinesthetic style (Exley 2003), multisensory approach (Benmarrakchi, Kafi and Elhore 2017) and the guidelines published by (Al-Wabil, Zaphiris and Wilson 2006) for web design involving individuals with dyslexia and dyscalculia.

3.1. Hypotheses

This study tested two hypotheses:

H1: Matching the training material to learners with SVD achieves significantly better reading performance compared to learners with VD.

H2: Matching the training material to learners with SVD achieves significantly better Learner Satisfaction (LS) compared to learners with VD.

### Table 1: Overview of Non E-learning Related Work

| Ref | Aim | T | P | A? | Evaluation |
|-----|-----|---|---|----|------------|
| Aidababah and Jusoh (2018) | Improve Arabic assistive technologies for individuals with dyslexia by proposing a set of usability features | NA | NA | No | Individuals with dyslexia were observed during performing specific tasks to extract usability features. (Qualitative) |
| Benmarrakchi, Kafi and Elhore (2017) | Propose a set of design guidelines based on spelling errors of individuals with dyslexia on an online text | NA | NA | No | Not evaluated. |
| AlRowais, Al-Dawsari and Hendley (2010) | Develop a framework for evaluating Arabic Training tools for dyslexia | NA | NA | No | Experts evaluated the framework using interviews and questionnaires (Qualitative) |

#### 3.2. Setup

**3.2.1. DysTypeTrain2 E-training System**

DysTypeTrain2 system is an updated version of DysTypeTrain developed by (Al-Dawsari and Hendley 2021; Alghabban, Al-Dawsari and Hendley 2021). It trains learners with dyslexia using eight reading activities where each activity consists of ten training exercises – giving a total of 80. The difficulty of these activities is gradually increasing. As in the DysTypeTrain, it uses the visuospatial/kinesthetic style (Exley 2003), multisensory approach (Benmarrakchi, Kafi and Elhore 2017) and the guidelines published by (Al-Wabil, Zaphiris and Wilson 2006) for web design accessibility for Arabic content. However, some updates applied to the DysTypeTrain2 system are:

(i) Providing the correct pronunciation of the wrong choice.

(ii) Hiding one of the wrong choices after three attempts to end up with only two choices and, thus, simplify the exercise.

(iii) Updating the e-training material to target SVD by combining short vowels (fat-ha /a/, kasra /i/ and dammah /u/) within a word, progressing from simple words (i.e. three letters’ words with only fat-ha short vowel) to advanced ones.
Table 2: Overview of E-learning Related Work

| Ref | Aim | T | P | A? | Evaluation |
|-----|-----|---|---|----|------------|
| Ouherrou et al. (2018) | Assess Arabic skills of learners with dyslexia. | G | S | No | System's usability was evaluated by specialists via the Heuristic evaluation (Qualitative). Feedback and comments were taken from children with dyslexia and specialists via a questionnaire. (Qualitative) |
| Al-Gharir (2019) | Enhance short-term memory of learners with dyslexia | GS | S | No | System’s usability was assessed by:
- Specialists via observations. (Qualitative)
- Children’s opinions. (Quantitative) |
| Al-Rubaidan et al. (2014) | Develop dyslexia phonological processing skills | GB | S | No | Left for later studies. |
| El Kah and Lakhouaja (2018) | Overcome reading and writing difficulties of dyslexia and dysgraphia | G | CP | No | Effectiveness of the system was evaluated by using pre and post-tests before and after children's interaction with the system. (Quantitative) |
| Alojo et al. (2018) | Teach Arabic letters for dyslexia | PG | An | No | System’s usability was evaluated by children with dyslexia. (Qualitative) |
| Alghabban and Hendley (2020) | Investigate the impact on learner satisfaction (LS) of adaptation based on a dyslexia type | G | W | Yes | LS. (Quantitative) |
| Benmarrakchi et al. (2017) | *Identify the relationship between dyslexia and learning styles. *Develop an adaptive game-based m-learning system considered their preferred learning style. | G | M | Yes | (Adaptive criteria is unclear). *Identification of the preferred learning style using a questionnaire (Quantitative). *Increased motivation and achievement through observation. (Qualitative) |

(i.e. four letters’ words with a mix of all three short vowels) as illustrated in Table 3. The incorrect words were chosen to target SVD difficulties too. This was achieved by choosing words similar to the correct answer in terms of letters and positions and differing only in the distribution of the short vowels within the word.

The training sessions’ layout was consistent throughout; that is keeping the audio icon, the image and the choices in the same place. The only difference was the training material at each session.

### 3.2.2. Instruments

The instruments below were used along with the system to conduct the study:

(i) **Consent form**: for parental approval since participants are under 18 years.

(ii) **Dyslexia diagnostic test**: for dyslexia type identification (VD or SVD).

(iii) **Demographic survey**: for collecting learner’s demographic information such as age, gender, grade, reading and non-reading difficulties.

(iv) **Pre & Post-tests**: for determining the knowledge level of the learner before and after using the system and then calculating the reading gain. Each test includes 10 words targeting SVD (ten words of different length with a combination of short vowels).

(v) **LS questionnaire**: for collecting learner’s satisfaction with the system. Due to their young age, the smileyometer (Read 2008) was used (see Figure 2).

(vi) **Observed fun and usability checklists**: for use whilst observing learners and to assess system usability (see Figure 3 and Figure 4).

![Smileyometer](image)

**Figure 2: Smileyometer**

**Table 3: E-Training Material**

| Activity | Content | #Letters within a word |
|----------|---------|------------------------|
| Fat-ha /a/ | Kasrah /i/ | Dammah /u/ |
| 1 | X | X |
| 2 | X | X |
| 3 | X | X |
| 4 | X | X |
| 5 | X | X |
| 6 | X | X |
| 7 | X | X |
| 8 | X | X |

### 3.3. Method

The study was subject to ethical approval by the institution and explicit parental approval for each learner. A mixed-methods approach was used to...
collect and analyze the data. Quantitative data was collected in the form of pre- & post-tests and learner’s satisfaction scores whereas qualitative data was collected from observations. The study took place in Riyadh, Saudi Arabia. The learners were welcomed and introduced to the objectives of the study. Then, their demographic information was collected, and their dyslexia type was determined. The pre-test was conducted to assess their prior reading level. Learners were divided into two groups, matched and mismatched, balanced by their prior reading performance level and age. The matched group contained learners with SVD while the mismatched one contained learners with VD. Both groups used the same version of the DysTypeTrain2 with training material matching the SVD (matched) group. Due to COVID-19, part of the study took place in person (face to face) while the other part took place remotely (online) via Zoom meetings with guidance from the experimenter, in a quiet room, within the learner’s school or home. Nobody was in the room except the learner and the experimenter. The learner sat in front of a desk with a laptop (or smartphone) while the experimenter sat next to them (or observed them via the laptop’s camera) observing and solving any technical problems. Learners worked individually with the system in eight experimental sessions: two sessions per learner per week. Each session had a duration of approximately 35 minutes and the total duration of the study was one month. At the beginning of the first session, the experimenter explained the system’s layout. During each session, the experimenter observed the learner’s fun and system usability and the corresponding checklists were filled. Other issues were also recorded. Neither the learner nor the experimenter was aware of the experimental condition to which the learner had been allocated. After finishing the study, the post-test and the satisfaction questionnaire were administered. The study followed the procedure illustrated in Figure 5.

Twenty-three female, native Arabic-speaking learners, already diagnosed with dyslexia, were recruited from different elementary schools. The learners were aged from 7 to 11 years (Grades 2 to 6). All had previous experience with electronic devices. The learners were assigned either to the mismatched group (n=10) or the matched one (n=13). Participants had approximately the same prior reading skill level (measured by the pre-test), with no statistically significant difference between the groups. Fourteen of 23 learners completed the study in school. Another eight learners completed it remotely. The remaining learner did not complete the study because the experimenter could not reach their contact number to conduct the study remotely. Therefore, the sample size dropped to 22 learners who completed the study with nine learners in the mismatched group and 13 in the matched one.

4. RESULTS AND DISCUSSION

The study was conducted with 22 female learners with dyslexia; 13 were assigned to the matched group and nine to the mismatched one. The groups of learners were homogeneous in terms of initial reading performance, age and language. The learners were in the second, third, fourth, fifth and sixth grades at Riyadh primary schools. The mean age of the matched group was 8.69 (SD = 1.18) whereas for the mismatched group was 8.44 (SD = 0.73). The learners were encouraged to take part in the study to improve their reading.

4.1. Quantitative Results

The pre & post-test and the LS scores were collected to measure both the learning gain (LG) (reading performance) and LS. Table 4 illustrates the mean and standard deviation of these data.

4.1.1. Learning Gain

The LG was calculated by subtracting the pre-test score from the post-test score to test Hypothesis H1. Table 4 shows that the LG of both the matched and mismatched group was positive (mean post-test score higher than the mean pre-test score).
This indicates that the reading performance of both groups was improved regardless of their dyslexia type. Whilst this suggests that the system and the training material were effective and the student’s learning was enhanced, it should be noted that the students were also taking conventional lessons over the period of the study. We should, therefore, be cautious in drawing any conclusion.

The mean LG of the mismatched group was higher than that of the matched group. We cannot therefore conclude that matching learning material to dyslexia type enhances student learning. Hypothesis H1 is, therefore, rejected.

This is not the result that was expected. It may be that this is just a consequence of the small number of experimental subjects and that repeating the study with a larger number of students would produce a different result.

Alternatively, it may just be that the skill targeted (reading words with short vowels) was one that the control group (students with VD) had still not mastered. The assumption of the experimental design was that students with VD would not benefit significantly from learning targeted at students with SVD (since this is not a difficulty that they have). However, if this was a skill that these students had yet to learn, then it may be that they would acquire this skill more quickly than those students for whom it would represent a greater challenge.

The LG results of this study were in line with the LG results of (Al-Dawsari and Hendley 2021) and therefore, they contradict the results in (Alghabban and Hendley 2020). This may be a result of several factors: (1) dyslexia types: in their study they recruited learners with VD and letter position dyslexia (LPD) instead of VD and SVD, (2) the number of participants: as they had 40 learners instead of 22 and (3) the experimental design: in their study the two experimental conditions used the adaptive and non-adaptive versions of their system.

4.1.2. Learner Satisfaction

LS was measured for both groups using the smileyometer (Read 2008) (see Figure 2) (Al-Dawsari and Hendley 2021), the mean LS of the matched and mismatched groups was almost the same. This indicates that both groups were highly satisfied with the system regardless of their dyslexia type. Therefore, H2 is not confirmed. This contradicts the findings of (Alghabban and Hendley 2020). However, in our case, the satisfaction scores of both groups was extremely high and there was, in effect, no opportunity to discriminate between the satisfaction of the two groups.

4.2. Qualitative Results

The qualitative data were collected by taking notes when observing learners’ behaviour at each session and was analyzed using the Thematic Content Analysis approach. The thematic map of the observations resulting from the analysis is illustrated in Figure 6. The observations were categorized into study mode, learners and the e-learning system.

In terms of positive effects, the learner can participate in the study from anywhere, at any time without being restricted to the school day and classes, as in the face-to-face mode. In terms of negative effects, the online mode affected the:

(i) Ability to observe the learner’s facial expressions: The video quality for these learners was poor and this affected the observation process.

(ii) Clarity of the system's audio: The system's audio was not clear to some learners (“The sound is not clear”, or they physically brought their ears close to the device), the
experiment, the experimenter had to repeat it (whether the question or the positive/negative feedback).

(iii) **Clarity of the system choices**: As the short vowels of the choices were too small ("The choices are all the same"), the experimenter had to enlarge the screen to make them clearer. Probably because the learners were using smartphones instead of a laptop as was the case in the face-to-face sessions.

In terms of **learners**, their fun was observed and a checklist was filled during the first experimental session. Table 5 illustrates that a majority of learners in both groups were happy, excited, and said some complimentary words ("The game is nice"). Two reasons could explain this: (1) the system used a new training strategy that captured the learner’s interest, as it is different from the strategy used by their teachers (either in the classroom or in their personal sessions) and (2) the interactive features of the system, especially when responding to the learners such as through feedback, replaying the question or displaying their overall progress.

**Table 5: Observed Fun Results**

| Group            | Excited | Bored | Happy | Sad | Compliment | Criticism |
|------------------|---------|-------|-------|-----|------------|-----------|
| Matched Group    | 9 (69%) | 0     | 8 (62%) | 0   | 10 (77%)   | 0         |
| Mismatched Group | 8 (89%) | 0     | 7 (78%) | 0   | 8 (89%)    | 0         |

Furthermore, the learners followed some practices to help them figure out the correct answer as illustrated in Table 6.

**Table 6: Learner practices**

| Practice                                               | Matched Group | Mismatched Group |
|--------------------------------------------------------|---------------|------------------|
| Listening carefully to the target word to              | 11 (84.6%)    | 7 (77.8%)        |
| discriminate between the short vowels                  |               |                  |
| Re-playing the target word more than once              | 6 (46.2%)     | 5 (55.6%)        |
| Spelling out the target word either aloud or by        | 8 (61.5%)     | 8 (88.9%)        |
| whispering (decoding the word)                         |               |                  |
| Identifying the correct choice’s style in a certain    | 1 (07.7%)     | 2 (22.2%)        |
| activities                                             |               |                  |
| Thinking then choosing                                 | 3 (23.1%)     | 2 (22.2%)        |

In terms of the **e-learning system**, a number of findings were revealed. Some of them were related to its usability while others to the repetition feature and negative feedback.

**Observed Usability.** The system’s usability was observed and a checklist was filled during the first experimental session without any assistance from the experimenter to the learner (Ismail et al. 2011). Table 7 illustrates that the image, text and buttons were clear for all learners in both groups whereas the audio was not clear for some of them because they conducted their experimental sessions remotely as mentioned earlier. Additionally, the majority of learners understood the buttons’ roles, system feedback and did not have to return to the previous page to re-correct their actions. However, the study instruction given in the first session might be unclear to some learners which affected their interaction with the system as illustrated in the last row of Table 7. So, the instructions were clarified later to help learners to proceed with the study.

**Table 7: Observed Usability Results**

| Usability Issue     | Matched Group | Mismatched Group |
|---------------------|---------------|------------------|
| Is sound clear?      | 8 (82%)       | 7 (78%)          |
| Is image clear?      | 13 (100%)     | 9 (100%)         |
| Is text clear?       | 13 (100%)     | 9 (100%)         |
| Choosing correct buttons? | 13 (100%)  | 9 (100%)         |
| Knowing what is going on? | 11 (85%)  | 9 (100%)         |
| Not going back?      | 13 (100%)     | 9 (100%)         |
| Knowing what to do?  | 6 (46%)       | 8 (68%)          |

**Repetition Feature.** All of the mismatched group learners and 12 learners of the matched group completed all eight training activities within the eight experimental sessions. The remaining learner of the matched group completed only seven because one of the activities spanned over two sessions. This learner faced different problems such as slow reading, severe difficulty in reading (difficulties in identifying letters and inability to combine letters to form the word), choosing quickly & randomly and problems in concentration. During the interaction with these activities, either the learner completed the activity from the first attempt or repeated it many times until they succeeded. Repeating the activity affected four learners of the mismatched group positively and two of the matched group through enhancing their focus and concentration on the question.

**Negative Feedback.** Two learners of the mismatched group did not like the system to spell out their mistakes when the negative feedback was launched. Therefore, they skipped the spelling feature. In the matched group, only one learner did that. This learner faced other difficulties such as hyperactivity and problems in concentration.

To summarize, the observations exposed that:

(i) Both face-to-face and online modes have pros and cons in terms of observation, system audio and study time & location.

(ii) The majority of learners in both groups were happy and excited with the system.

(iii) Different practices were followed by the learners to figure out the correct answer, such as re-playing the question to identify its phonemes.
(iv) The system was usable and understandable.
(v) The repetition feature enhanced the learner’s focus to choose correctly.
(vi) A minority of learners disliked the negative feedback especially when their mistakes were re-pronounced and they reacted by skipping to the next exercise.

5. CONCLUSION AND FUTURE WORK

This study investigated the impact on reading performance and LS & behaviour of matching e-training material to Arabic dyslexia type. Arabic was targeted due to the lack of studies in this language (Benmarrakchi, Kafi and Elhore 2017; Mahfoudhi, Everatt and Elbeheri 2011). The lack of rigorously designed and controlled experimental evaluations in previous studies (Benmarrakchi, Kafi and Elhore 2017; Aldabaybah and Jusoh 2018) was addressed too. A mixed-methods approach of qualitative and quantitative analysis was used. The study was conducted with 22 Arabic learners with dyslexia who were distributed into two groups; matched and mismatched. The matched group included learners with SVD whereas the mismatched group included learners with VD. The study was conducted in two different modes due to COVID-19: face-to-face mode and online mode. The online mode was beneficial in terms of the flexibility of day and time to run the study. The learner was not restricted to the school schedule. However, the online mode affected the ability to observe the facial expressions and the clarity of the audio and choices. In addition, a majority of the system’s features were accessible, usable and understandable. The quantitative findings revealed a positive effect on LG and LS regardless of dyslexia type. The qualitative findings revealed that the majority of learners were happy and excited in their experimental sessions. Additionally, the learners used different ways to choose correctly in each activity, for instance, spelling out the question and re-playing it. It was also clear that many learners had additional problems that affected their ability to read, such as hyperactivity. Despite the positive results of this study, there are several limitations. One is the small number of learners which limits the conclusions that can be drawn and the generalizability of the results. Secondly, only two dyslexia types were targeted by the study. Therefore, further investigation is required to check the possibility of generalizing these findings to other Arabic dyslexia types. Thirdly, Arabic has a very different structure and orthography from many other languages, such as English. Thus, further investigation is required to check the possibility of generalizing the research results to different languages and cultures as well as males and other age groups. Moreover, whether these results can contribute to other learning domains, such as mathematics, is unclear. Finally, it is worth mentioning, that no results were statistically significant and we cannot build any conclusions from them due to the small number of learners who participated and the high probability of getting these results by chance. In future, more participants should be enrolled and choosing another dyslexia characteristic will be a good choice for testing.

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