HCI: Adaptive Learning for Dyslexic Users

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A thesis submitted to

the University of Birmingham

for the degree of

DOCTOR OF PHILOSOPHY

School of Computer Science
College of Engineering and Physical Science
The University of Birmingham
September 2022

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Abstract

Dyslexia is a lifelong reading difficulty that exists everywhere regardless of an individual's language or culture. They face various difficulties in reading, writing and spelling. Whilst it is impossible to find two individuals with dyslexia with exactly the same difficulties, most current research treated them similarly. Further, the manifestation of dyslexia is affected by the language's structure and orthography. Because of the lack of research on Arabic dyslexia, especially on the benefits of adaptive e-learning in this domain, this research aimed to understand the impact of adapting the e-training material to the characteristics of a learner with Arabic dyslexia on their reading performance, satisfaction and behaviour. The focus was on Arabic dyslexia types as the learner's characteristic because they reflect the reading difficulties they face with reading being their main problem. We first analysed the literature on Arabic dyslexia and current e-learning systems that support individuals with dyslexia to understand dyslexia and to identify the weaknesses in these systems. Next, we conducted two controlled experiments to understand the effect of matching the training material to one of the Arabic dyslexia types on the learner's reading performance, satisfaction and behaviour and to validate the developed system and tools. Because each experiment focused on vowel letter dyslexia and short vowel dyslexia, we designed a dyslexia diagnostic test to determine the Arabic dyslexia type that a learner with Arabic dyslexia has. In each experiment, we measured reading improvement and learner satisfaction and observed the learner's behaviour. The findings showed that the reading of learners with Arabic vowel letter dyslexia and short vowel dyslexia improved similarly and that all learners were highly satisfied with the system. From these two experiments, we discovered a new common Arabic dyslexia reading difficulty named "short vowel dyslexia". Therefore, we noticed that the literature and practice were inconsistent. So, we designed a questionnaire to understand dyslexia in practice from the perspective of special education teachers. We found that visual dyslexia is also common among learners with Arabic dyslexia. Therefore, the final experiment targeted vowel letter dyslexia and visual dyslexia taking into account lessons learned from the first two experiments. In this experiment, the training material was adapted to the learner's Arabic dyslexia type (vowel letter dyslexia and visual dyslexia). We can

conclude that adapting training material to learner's Arabic dyslexia type improved their reading and the learners were highly satisfied in both conditions and no opportunity to discriminate between them. On the other hand, we cannot conclude that what has been learned can be generalised to other words with similar features. Finally, learners were happy and engaged as they learned and they followed some good practices to improve their learning.

To my parents and my children ..

Acknowledgements

First of all, I would like to express my great attitude to Almighty Allah for giving me the strength and opportunity to complete this long tough journey that ended by writing this thesis.

I would like to express my thankfulness to my supervisor Mr.Robert Hendley for his guidance starting from title selection throughout choosing my research gap and ending with thesis writing. Without his guidance, motivation and patience, I would not be able to complete my journey. I do appreciate his continuous support and listening to me. He is my mentor and a better advisor for my doctorate study beyond the imagination.

I would also like to thank the government of the Kingdom of Saudi Arabia for funding me and my studies, including funding all academic and holiday trips. In addition, I would like to thank the Ministry of Education in the Kingdom of Saudi Arabia and all the schools' staff for accepting to conduct my experiments and to thank the students who participated in these experiments.

I am grateful to my mom (Mona), dad (Mohammed), brother (Ateeq) and sisters (Maad, Yara and Aseel), who remembered me in their prayers and supported me during my PhD journey and all my life. I am nothing without my amazing family. They have given me all the support I need, and they have encouraged and motivated me to achieve my goals. I actually have the best family ever. Thanks to you all, and I do apologize for all my complaints that you have listened to from me, day and night. I would also like to extend special thanks to my friends who listened to me, supported me and prayed for me, especially Amani Al-Malik, Wed Ghabban, Sarah Al-Zeer, Sarah Al-Shaikhi, Aliya Al-Saleh, Nojood Al-Ghamdi, Lama Al-Qazlan, Weam Al-Ghabban, Nouf Al-Harbi, Haneen Yahya and Randa Al-Lafi.

Finally, I would like to say a big thank you to my children (Lara and Abdullah), who have been with me throughout my journey. Thank you for your great patience and understanding in my good and bad times as well as when I was very busy. Thank you for helping me and taking care of me. I am so grateful that you have calmed me down, especially on my sad days and that you have entertained me during my PhD and the coronavirus outbreak. I cannot imagine what my journey would be like without you. ***Thanks, every one, one by one.***

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List of Abbreviations

Abbreviation	Meaning
ADHD	Attention-Deficit/Hyperactivity Disorder
BDA	British Dyslexia Association
DBMS	Database Management System
HCI	Human Computer Interaction
IDE	Integrated Development Environment
KSA	Kingdom of Saudi Arabia
PHP	Hypertext Pre-Processor

Chapter 1

Introduction

1.1 Introduction

Reading is one of the most important basic language skills that should be learned. It is the key to learning other concepts. There are different classes of readers; one class can read fluently, easily, without errors and understand automatically, whereas another class faces difficulties and exhaustion when reading and understanding. Therefore, they are often excluded socially and educationally, especially in classrooms (Mastropavlou and Zakopoulou, 2013). Such readers may have dyslexia.

Dyslexia was identified more than one hundred years ago. It is a Greek term that is composed of the prefix ***impaired*** and the base ***word*** which results in ***difficulty in words*** (Berninger et al., 2008). Around 15-20 % of the worldwide population has a learning difficulty, of which 70-80 % have dyslexia (Alghabban et al., 2017). Dyslexia is defined as a specific learning disability (Mastropavlou and Zakopoulou, 2013) that is independent of intelligence (Walker, 2014). It is widely believed that dyslexia is a neurobiological issue (Mastropavlou and Zakopoulou, 2013). Individuals with dyslexia suffer from a disorder in language processing, specifically its phonological component which leads to several symptoms: (1) inaccurate and/or slow word recognition (2) spelling errors (3) poor decoding ability (Mastropavlou and Zakopoulou, 2013) (4) word repetition or addition and (5) character deletion and transposition (Tafti et al., 2009).

The manifestation of dyslexia is language-dependant as it is affected by the language's structure and orthography. Different languages affect individuals with dyslexia differently depending on whether the script is transparent or not. A transparent script, such as Turkish, has a one-to-one relationship between symbols and phonemes, whereas a non-transparent script, such as English, has a much more complex relationship between these (Elbeheri et al., 2006). Arabic, is atypical in its transparency (Elbeheri et al., 2006). It can be considered as either transparent or not, depending on the use of short vowels (Mahfoudhi et al., 2011). Whilst Arabic is widely spoken (Mahfoudhi

et al., 2011), few studies have explored Arabic dyslexia (Alghabban et al., 2021). Therefore, this research targets learners with Arabic dyslexia.

The emergence of e-learning systems gives the opportunity for a wider learner community to access educational content. This large learner community has raised a variety of individual needs that should be considered in e-learning systems in order to provide an adequate learning experience (Essalmi et al., 2010a). Unfortunately, traditional e-learning systems suffer from several drawbacks compared to real-world teaching (Essalmi et al., 2010b), such as providing the same learning content to all learners regardless of their individual needs which in turn negatively affects the effectiveness of the learning process and thus dissatisfies and demotivates learners (Schiaffino et al., 2008). Therefore, this research aims to identify the learners' needs, to provide the learning content that suits these needs.

Adaptive e-learning systems provide the learner with a personalised online educational environment independent of time and space, allowing them to learn as if there is a personal tutor. They aim to improve the learners' experience and thus to increase their satisfaction and engagement and the effectiveness of the learning process (Maravanyika et al., 2017). E-learning systems can be adapted using a variety of learner characteristics such as learner's knowledge level (Mitrovic, 2003) and learning styles (Papanikolaou et al., 2003; Alshammari et al., 2015c). The same method can be applied to learners with dyslexia.

We suggest studying the impact of adapting the learning content of an e-learning system to the needs of learners with Arabic dyslexia, on their reading performance and satisfaction. There are a variety of characteristics for these learners that can be used as an adaptation criterion. However, it is difficult and impractical to study them all. So, this research has focused on Arabic dyslexia types.

The reminder of this chapter presents an overview and introduces the relevant background and research studies. In addition, it outlines the main goal of this research, the research questions followed by the research methodology. It, then, highlights the research contributions to the existing literature and provides a list of peer-reviewed publications resulting from this research. Finally, the structure of the thesis is given.

1.2 Background and Motivation

Dyslexia can be defined as a specific, long-term learning disability that affects the acquisition and development of reading and spelling and thus negatively influences the academic achievement and/or activities of the daily life of an individual (Habib and Giraud, 2013; Mastropavlou and Zakopoulou, 2013). (Lyon et al., 2003; Habib and Giraud, 2013) indicated that dyslexia has a

neurobiological origin, possibly due to genetics, and is primarily linked to the phonological level of processing.

Dyslexia can be classified into developmental and acquired dyslexia depending on its main cause. Developmental dyslexia is believed to be genetic in its origin and inherited through generations (Grigorenko et al., 1997; Walker, 2014; Hamid et al., 2015). It is caused by a deficit in some parts of the brain that are responsible for reading (Cao et al., 2006; Béland and Mimouni, 2001). Acquired dyslexia is caused by external factors such as damage to the brain through trauma. Acquired dyslexia affects a small number of individuals after birth (Walker, 2014; Hamid et al., 2015) therefore, this research focuses on developmental dyslexia.

Individuals with dyslexia face different difficulties (Alsobhi and Abeysinghe, 2013) with different degrees and forms of severity (Al-Wabil et al., 2006). It is unusual to find two individuals with dyslexia with exactly the same symptoms. Therefore, each individual with dyslexia faces different problems in learning. Hence, each one should ideally be treated as a seperate case to meet their needs (Alsobhi and Abeysinghe, 2013).

Individuals with dyslexia have a variety of symptoms such as slow reading (Habib and Giraud, 2013), migrating letters within the word or between words, problems in identifying letters (Friedmann and Coltheart, 2016), slow writing, spelling errors (Walker, 2014), time management and organizational problems (MacDougall, 2009), and problems in their short-term memory (Tafti et al., 2009).

Dyslexia can co-occur with other developmental disorders (Habib and Giraud, 2013) such as developmental dysphasia (oral expressive and/or receptive language delay and difficulties), developmental dyspraxia (motor coordination disorders), Attention-Deficit/Hyperactivity Disorder (ADHD), Affective disorders (shyness, low self-esteem (Glazzard, 2010)) and Dyscalculia (mathematics learning is affected).

On the other hand, people have argued that some individuals with dyslexia are of intellectual giftedness (Habib and Giraud, 2013). They may be strong in creative thinking, getting information through their physical senses (LaFrance, 1997), spatial awareness, problem solving (Waterfield, 2002) and pictorial thinking (Davis and Braun, 2011, p. 100).

To provide individuals with dyslexia with a suitable solution, their difficulties and symptoms must be understood. Hence, classifying them into different types is beneficial (Alsobhi et al., 2014; Friedmann and Coltheart, 2016). Helmer Myklebust was the first educational psychologist who suggested classifying developmental dyslexia into different types (Friedmann and Coltheart, 2016). There are different attempts to classify developmental dyslexia. One attempt classified developmental dyslexia based on symptoms known as Ingram's classification (Alsobhi et al., 2014). Another attempt classified them based on a deficit in the components of the dual-route model for single-word

reading or in the connections between them, as suggested by (Friedmann and Coltheart, 2016) to determine the different dyslexia types. Whilst they explain the reading aloud process of a single-word straightforwardly, they also highlight the essential role that each component of the model plays. Consequently, any error in one of the components results in a reading deficit and thus, a dyslexia type (Friedmann and Haddad-Hanna, 2014). This research has adopted this classification. Developmental dyslexia can be classified, based on that model, into two main categories ***Peripheral Dyslexias*** and ***Central Dyslexias***. Each one contains five dyslexia types. In order to understand these types, the process of normal reading aloud using the dual-route model is explained in Chapter 2.

The manifestation of dyslexia is sensitive to language because it is affected by the language's orthography and structure. However, Arabic dyslexia suffers from lack of research (Alghabban et al., 2021). Therefore, this research focuses on Arabic dyslexia.

The Arabic language is the fifth most spoken language in terms of native speakers. Over 200 million people, especially in the Middle East and North Africa, speak Arabic as their first language. Moreover, it is used as a second language by millions of Muslims because it is the language of the Holy Quran (Mahfoudhi et al., 2011).

Many Arabic features can be partially responsible for the manifestation of dyslexia such as its cursive nature and the different shapes that each letter can take based on its position within the word (Elbeheri, 2005). According to (Friedmann and Haddad-Hanna, 2014), Arabic developmental dyslexia is classified into seven types based on the deficits in the dual-route model. In this research, three types are the focus, due to their frequency among learners with Arabic dyslexia according to both the literature (Friedmann and Haddad-Hanna, 2014) and practice: letter position dyslexia, vowel letter dyslexia and visual dyslexia.

Individuals with letter position dyslexia face problems in identifying the letter order within the word. Therefore, the letters migrate within the word, especially the middle letters. On the other hand, individuals with vowel letter dyslexia face problems when reading new or non-words by adding, deleting, transposing and replacing vowel letters, especially when the result is a known word. Finally, reading the target word as another visually similar word because of deletions, additions and substitutions of letters within a word are symptoms of visual dyslexia (Friedmann and Haddad-Hanna, 2014; Friedmann and Coltheart, 2016).

Different interventions exist to support individuals with dyslexia. In the context of learning, teachers can use an individual plan to support each learner with dyslexia (Béland and Mimouni, 2001; Sampath et al., 2010) as each learner has unique difficulties. With the emergence of e-learning systems, more learning opportunities became available to a wider learner community independent

of time and location. More learners lead to more individual needs which are not considered by traditional e-learning systems (Essalmi et al., 2010a). Therefore, adaptation based on needs, should be used.

Adaptation can be defined in the context of e-learning systems as providing a personalised teaching and education environment by monitoring the learner's needs (Maravanyika et al., 2017).

Different learner characteristics can be used to adapt the e-learning systems such as learners' knowledge level and learning styles. In terms of knowledge level, (Mitrovic, 2003) has developed SQLT-Web which is an adaptive online SQL tutoring system for teaching SQL based on the knowledge level of the learners. Other studies have used the learning style as an adaptation criterion. For instance, the INSPIRE system (Papanikolaou et al., 2003) and AdaptLearn system (Alshammari et al., 2015c) have personalised the learning paths based on the learning style of the learner.

Learners with dyslexia, like all learners, have different characteristics that also should be considered in adaptive e-learning systems. For instance, an adaptive learning environment provided by (Benmarrakchi et al., 2017c) for learners with dyslexia has considered their learning styles and cognitive traits. A combination of learning styles and dyslexia types has been considered by (Alsobhi et al., 2015b), whereas (Chitra and Umamaheswari, 2018) considered the knowledge level. More characteristics of learners with dyslexia have been considered by (Alghabban and Hendley, 2020b) and in the Dyslexia Adaptive E-learning framework (Alsobhi et al., 2015a).

Because this research targets Arabic dyslexia, then it is important to explore the existing research in this area. Some research considered adaptivity when they developed e-learning systems to teach Arab individuals with dyslexia while others did not. In terms of non-adaptivity, (Al-Rubaian et al., 2014) proposed to develop the phonological processing skills of individuals with dyslexia via designing serious games using Brain-Computer Interface. 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.

Further, a study was conducted by (Aljojo et al., 2018) to teach Arabic letters for dyslexia. They developed a puzzle game-based system along with eye-tracking and chatbot features. This system intended to assist the child in correctly pronouncing the Arabic letters using different short vowels. System usability was evaluated by the children in terms of learnability, efficiency, memorability, errors and satisfaction. Each task of the system was evaluated. However, their findings were not discussed clearly.

In terms of adaptivity, Arabic dyslexia types have been considered a characteristic of learners with Arabic dyslexia in adaptive e-learning systems. For instance, the effect of adapting learning material to Arabic dyslexia types on children's satisfaction has been investigated by (Alghabban

and Hendley, 2020b). They implemented an adaptive e-learning system to train children with dyslexia in reading skills. The system was evaluated in terms of children's satisfaction. However, the study did not take into account learning performance.

The learning style of learners with Arabic dyslexia has been considered as another characteristic. (Benmarrakchi et al., 2017b) aimed to enhance the fundamental skills of the children with dyslexia such as reading, writing, short-term memory and Arabic orthography. A framework for an adaptive m-learning system was developed based on learning style to support these children. However, the system's effectiveness cannot be understood because the evaluation methodology was not presented.

To conclude, there is a lack of research, especially in adaptive e-learning systems of Arabic dyslexia that draws upon a theoretical framework to understand dyslexia and guide the design of adaptive e-learning systems. Further, most of this research has treated individuals with dyslexia similarly, lacks well-designed experiments and the evaluation of their effectiveness is limited. Therefore, this research builds upon a deep understanding of Arabic dyslexia reading difficulties and their effects from the theoretical framework perspective, the dual-route model for single-word reading, and combines this understanding with existing practice to drive adaptation based on dyslexia reading difficulties (Arabic dyslexia types) in order to understand and enhance the effectiveness of the learning process and thus improve the learner's reading.

1.3 Research Questions

This research began with this main question:

Q: Does adaptation based on the characteristics of learners with dyslexia improve their skills?

However, answering this question in this form is difficult because there are a variety of learners' characteristics that can be addressed and a set of skills that can be improved which cannot all be covered due to practical reasons. Therefore, we should specify the learner's characteristics and the skill to be improved. In terms of the learner's characteristics, there is a list of existing learner's characteristics such as knowledge level and learning style (Brusilovsky and Millán, 2007; Felder et al., 1988) which can be applied to all types of learners. As this research targets a special group of learners, learners with dyslexia, there are special characteristics that are only applied to them such as their symptoms (the difficulties they face). Learners with dyslexia face a wide range of difficulties some of which are reading difficulties while others are writing and spelling. This research focused on the reading difficulty, because it is the main difficulty faced by an individual with dyslexia (Shaywitz, 1998; Cao et al., 2006). Since the language affects the manifestation of dyslexia and the Arabic language suffers from limited research, so Arabic dyslexia is adopted by

this research and thus Arabic dyslexia reading difficulties are targeted. Different attempts exist in the literature to understand the reading problems of dyslexia. One is classifying dyslexia into types using the dual-route model for single-word reading as proposed by (Friedmann and Haddad-Hanna, 2014). They have explained the various deficiencies that can arise in any component of that model that leads to an Arabic dyslexia type. Each type can be recognised through the effect that results from the deficit in a component of the dual-route model. The dual-route model helps in understanding the main deficit of a specific Arabic dyslexia type and its implications, leading to determining the type of intervention that best suits this Arabic dyslexia type. Consequently, the Arabic dyslexia types are the learner characteristic used in this research. In terms of skills to be improved, learners with Arabic dyslexia possess a variety of unmastered skills resulting from the difficulties they face. As this research targets some of the Arabic dyslexia types, which are mainly reading difficulties, these difficulties have directed this research to target the reading skills to reduce the severity of the Arabic dyslexia types. To measure the improvement of the reading skill in this research and thus the effect of adaptation, the learning gain was calculated. Learner satisfaction can reflect the learner's motivation and engagement in the learning process. It also can show to what extent the system fits the needs of the learner. Thus, the learner satisfaction is an important factor for evaluating the effectiveness of the e-learning system and plays an essential role in the learning process (Alshammari et al., 2015d; Alakkas, 2016). Precisely, learner satisfaction can be used as an indirect way of measuring the effect of adaptation, so it was also measured in this research.

So, the previous broad question can be narrowed down to these smaller questions:

Q1: Is there a significant difference in learning gain when adapting the training material of an e-learning system to the Arabic dyslexia types compared to the non-adapted version?

Q2: Is there a significant difference in learner satisfaction when adapting the training material of an e-learning system to the Arabic dyslexia types compared to the non-adapted version?

1.4 Research Methodology

To investigate the impact of adapting the training material of the e-learning system to Arabic dyslexia types on learners' reading performance, satisfaction and behaviour, three controlled experiments have been conducted. In all experiments, the between-subjects experimental design was used where each learner experiences only one experimental condition. This is because we do not want the learning effect to be carried by the learner from one condition to another (Keren and

Raaijmakers, 1988). Each experiment followed the same approach, each with different learners with Arabic dyslexia and different training material. The experiments were conducted with primary school learners with Arabic dyslexia in the Kingdom of Saudi Arabia (KSA) due to practical reasons; (1) KSA is my home country, (2) learners in KSA are native Arabic speakers and (3) they are easily accessible. Unfortunately, and due to COVID-19, the schools were closed on the 9th of March 2020, therefore, part of the first and second experiments was conducted physically in Riyadh primary schools in KSA while the other part switched to virtual mode via Zoom Meetings and Microsoft Teams. The last experiment was conducted totally remotely.

The first two experiments were conducted as pilots to validate experimental design, the developed system and the tools in these experiments. In these experiments, it was hypothesised that there would be a significant difference in learning gain and learner satisfaction between the matched and mismatched groups. Two Arabic dyslexia types were targeted in these two experiments; vowel letter dyslexia and short vowel dyslexia. Vowel letter dyslexia was chosen because it is common among learners with Arabic dyslexia as reported in the literature (Friedmann and Haddad-Hanna, 2014) whereas short vowel dyslexia was found to be common among these learners, in practice. In these experiments, learners with Arabic dyslexia were diagnosed to determine their Arabic dyslexia type (vowel letter dyslexia or short vowel dyslexia). Then, their demographic information was completed by their teachers and they were registered in the system by the experimenter. The participants took a pre-test related to the training material to assess their initial reading level. Then, they were divided into two groups balanced in terms of number of learners, age and initial reading level. All learners with Arabic vowel letter dyslexia were in one group while learners with Arabic short vowel dyslexia were in the other. All participants in both experiments were female because the experimenter cannot enter male schools due to the policies of the Ministry of Education in KSA which, in turn, provided more control over the experiments. The participants were able to use the system only with the attendance of the experimenter. They should complete 80 training activities in eight experimental sessions within four weeks at maximum. Each experimental session lasted no more than 35 minutes. All participants, who completed all the experimental sessions, have completed a post-test similar to the pre-test and a learner satisfaction questionnaire. Subtracting the pre-test score from the post-test score was used as a proxy for measuring the learning gain. The learning gain and the learner satisfaction scores were compared between the matched group and the mismatched group. During the experiment, the participants' behaviours were observed and recorded. The first experiment targeted learners with Arabic dyslexia in fourth, fifth and sixth grades. This range of grades was widened to include the second and third grades in the second experiment in order to recruit more learners.

After collecting and analysing the data, it was found that the learning gain for both groups was improved without any significant differences between the groups and the learners were highly satisfied with the system regardless of their Arabic dyslexia type which partially contradicts the results of (Alghabban and Hendley, 2020b,a).

Previous experiments have been built upon our understanding of dyslexia in the literature that does not quite match up with practice. So, it is important to understand dyslexia in practice in order to combine both literature and practice to build the last and main experiment.

Therefore, an exploratory questionnaire was designed, piloted and published to special education teachers, who are experts in the field, to explore the practice in KSA schools, from their perspective. The responses were collected, analysed and discussed leading to the last experiment in this research. In the last experiment, it was hypothesised that there is a significant difference in learning gain and learner satisfaction between the adaptive and non-adaptive groups when adapting the training material to Arabic dyslexia type. Based on the findings of the questionnaire, vowel letter dyslexia and visual dyslexia were the two Arabic dyslexia types that were targeted. The adaptive/non-adaptive approach was used and thus two versions of the e-learning system were developed. One version provided the adaptation process whereas the other version did not. This experiment followed the same procedure and measured the same measurements as the first two. The ability to generalise the learning to other contexts was also explored. As the last experiment was conducted remotely, it was possible to recruit learners with Arabic dyslexia in Saudi primary schools regardless of their gender and location.

1.5 Research Contribution

The contributions of this research are:

- The literature on Arabic dyslexia and the current e-learning systems to support such individuals have been analysed to understand dyslexia and identify the weaknesses and limitations of these systems.
- A controlled experiment has been designed to evaluate the effect of adaptation to Arabic dyslexia types on learners' learning gain, satisfaction and behaviour which in turn built an understanding of the effect of adaptation on learners with dyslexia.
- A dyslexia diagnostic test (reading test) has been designed to determine the learner's Arabic dyslexia type (vowel letter dyslexia, visual dyslexia, both or another Arabic dyslexia type) (Appendix B).
- The satisfaction in e-learning questionnaire (Siritongthaworn and Krairit, 2006) has been supported with a Smileyometer instead of using the original 5-point Likert scale to use the

questionnaire with children (Appendix E).

- A new common Arabic dyslexia reading difficulty among learners with Arabic dyslexia in Saudi primary schools has been discovered. This is mixing between phonemes of the three essential short vowels (fat-ha /a/, kasra /i/ and dammah /u/), ـَ ، ـِ ، ـُ within a word during reading aloud. This, in turn, may lead to reading another known word such as reading the word "lo'ab" which means "toys" as "la'eb" which means "played".
- An understanding of dyslexia from practice and what teachers believe works well for them has been built by identifying important user attributes (e.g. dyslexia type, motivation, attention), successful teaching strategies, important interaction issues and important metrics when evaluating e-learning systems.
- The design of adaptive systems for teaching learners with dyslexia has been informed by determining the features that should be represented in the learner model and then determining the appropriate adaptation strategies.

1.6 List of Publications

A number of research papers resulting from this work have been published:

- Chapter 5 "Quantitative Results" - **Al-Dawsari, H.**, & Hendley, R. (2021). The Effect of Matching Learning Material to Learners' Dyslexia Type on Reading Performance, In *Advances in Software Engineering, Education, and e-Learning*, p. 837-845. Springer.
- Chapter 5 "Qualitative Results" - Al-Ghabban, W., **Al-Dawsari, H.**, & Hendley, R. (2021). Understanding the Impact on Learners' Reading Performance and Behaviour of Matching E-Learning Material to Dyslexia Type and Reading Skill Level, In *International Conference on Human-Computer Interaction*, p. 135-154. Springer.
- Chapter 6 - **Al-Dawsari, H.**, & Hendley, R. (2022). The Impact of Matching E-Training Material To Dyslexia Type On Reading Performance and Learner Satisfaction & Behaviour. In *35th International BCS Human-Computer Interaction conference*. In Press.
- Chapter 7 - **Al-Dawsari, H.**, & Hendley, R. (2022). Understanding the Needs of Arab Learners with Dyslexia for Adaptive Systems. In *35th International BCS Human-Computer Interaction conference*. In Press.

1.7 Thesis Structure

This thesis is composed of nine chapters including this chapter. Chapter 2 is about dyslexia. It explores its definition, causes and characteristics (difficulties and strengths). Because dyslexia is

a reading difficulty, the process of normal reading aloud a single word using the dual-route model is presented along with the dyslexia types. In addition, the manifestation of dyslexia is language-dependent. Since Arabic dyslexia is the target of this research, Arabic orthography, cultural factors and Arabic dyslexia types are also discussed. Finally, both technological and non-technological interventions, to reduce the long-term problems faced by individuals with dyslexia and to promote future success in both school and the workplace, are explored.

Chapter 3 outlines the adaptation concept and the different learners' characteristics that can be used to adapt an e-learning system. The way of adapting a system and the different models used in an adaptive system are also presented. Examples of related studies which have attempted to adapt an e-learning system for learners with dyslexia are explored and their issues are identified.

Chapter 4 presents the motivation for adapting an e-learning system based on Arabic dyslexia types. It briefly discusses the three experiments required to investigate the impact of this adaptation on learner's reading performance. Further, an exploratory questionnaire designed to explore the practice from the special education teachers' perspective is also outlined. Later in this chapter, the framework and the way to implement it are presented.

Chapters 5, 6 and 8 explain the three experiments that have been conducted to investigate the impact of adapting an e-learning system to learners' Arabic dyslexia types on their reading performance, satisfaction and behaviour. Each experiment is described separately and in detail, including its own specific objectives, hypotheses, method, results and discussions.

In the first two experiments, results were not statistically significant in learner's learning gain or satisfaction and the literature did not match practice. So, we want to understand dyslexia in practice from the perspective of experts in the field (special education teachers) to guide the design of the last and main experiment. This is why an exploratory questionnaire was designed and published to special education teachers. Chapter 7 focuses on this questionnaire in detail.

Finally, Chapter 9 summarises the whole research, re-visits the research questions and highlights the main contribution of this research. In addition, the limitations of this research are also presented followed by suggestions for future research.

Chapter 2

Dyslexia

2.1 Introduction

Dyslexia is a reading difficulty that can be found anywhere regardless of race and ethnicity. It is widely believed that dyslexia is neurological in origin and can be inherited through generations. People with dyslexia face numerous difficulties that affect their education and whole life in general. So, dyslexia should be understood in order to provide its individuals with the support they need. Therefore, this chapter presents the different attempts to define dyslexia along with its causes and the different symptoms that identify them. Another way of understanding dyslexia is by classifying it into different types based on different criteria which are also discussed in this chapter. One of the most powerful approaches is classifying dyslexia based on the affected component of the dual-route model for single-word reading as this model describes the reading aloud process in a straightforward way. So, the reading process via this model and the dyslexia types are detailed. Since dyslexia difficulties are affected by the language, and this research targets Arabic, then Arabic dyslexia is also discussed along with Arabic orthography and Arabic dyslexia types. Finally, the different interventions offered to individuals with dyslexia to help them overcome their difficulties are presented.

2.2 Dyslexia

Dyslexia was first formally identified more than one hundred years ago, in 1887, by Dr.Berlin (Critchley, 1968; Berninger et al., 2008; Alsobhi et al., 2014). Dyslexia is a Greek term that is composed of the prefix ***impaired*** and the base ***word*** resulting in ***difficulty in words*** (Critchley, 1968; Berninger et al., 2008; Alsobhi et al., 2014). Around 15-20% of the worldwide population has a learning difficulty, of which 70-80% has dyslexia (Alghabban et al., 2017) with different degrees of severity.

There have been many attempts to define dyslexia in the literature (Alsobhi et al., 2014) but there

is no single definition for dyslexia that is universally accepted (Critchley, 1968; Alsobhi et al., 2014). Different authors with different scientific backgrounds have attempted to define dyslexia based on the differences in conceptualizing dyslexia's fundamental cause (Alsobhi et al., 2014). These differences in defining dyslexia and determining its main cause is addressed in the following sub-sections. In addition, the different dyslexia symptoms in term of strengths (e.g. creativity (LaFrance, 1997) and spatial awareness (Waterfield, 2002)) and weaknesses (e.g. reading and short-term memory problems (Tafti et al., 2009; Alghabban et al., 2017)) are also presented.

To understand dyslexia, it has been classified into different types using different criteria. For instance, Ingram's classification classified dyslexia based on its symptoms (Alsobhi et al., 2014). Another classification was based on the affected part (component or connection between components) of the dual-route model for single word reading (Friedmann and Coltheart, 2016). This classification is adopted by this research. Details are addressed below.

2.2.1 Definition of Dyslexia

There have been various attempts to define dyslexia. In 1968, (Critchley, 1968) defined developmental dyslexia as a long-life specific learning difficulty in reading, which is often genetic in origin and exists without (1) impairments in hearing or vision and (2) brain deficit regardless of the general intelligence level. Further, this difficulty is associated with spelling difficulty. This is consistent with the working definition in 1994 which defined dyslexia as one of the learning disability types characterised by difficulties in decoding a single word which are unexpected in relation to age, cognitive and academic abilities. These difficulties usually result from imperfect phonological processing rather than from a sensory deficit or general developmental disability. In addition to reading problems, dyslexia may include problems with both writing and spelling (Lyon et al., 2003). (Lyon et al., 2003) enhanced the previous definition in 2003. They defined dyslexia as a specific learning disability, which originally resulted from a neurobiological problem. It can be recognised by difficulties in recognizing words accurately and/or fluently and by poor spelling and decoding abilities which typically result from a disorder in the language phonological component. Other consequences may include reading comprehension problems and a reduced reading experience that can impede the development of vocabulary and background knowledge.

In the UK there is no legal definition of dyslexia although it is recognized as a disability. However, the British Dyslexia Association (BDA) adopted the definition of DCSF Expert Advisory Group on Dyslexia (Singleton, 2009, p. 16-17):

"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".

On the other hand, in the USA, a widely accepted dyslexia definition is the one proposed by the International Dyslexia Association (Singleton, 2009):

"Dyslexia is one of several distinct learning disabilities. It is a specific language-based disorder of constitutional origin characterised by difficulties in single-word decoding".

Finally, dyslexia has been defined by the main international classification, ICD-10 (WHO, 1992) as:

"A specific and significant impairment in the development of reading skills, which is not solely accounted for by mental age, visual acuity problems, or inadequate schooling".

So, it is widely believed that dyslexia is neurological in origin. But, there is no formal dyslexia definition that is accepted and generalised. However, research has agreed on multiple characteristics that identify dyslexia besides problems in phonological processing that causes reading difficulties, such as difficulties in spelling and writing.

2.2.2 Causes of Dyslexia

Dyslexia is classified, based on its main cause, into developmental and acquired dyslexia (Walker, 2014; Hamid et al., 2015). There was a strong debate on the main cause of developmental dyslexia . (Critchley, 1968) has pointed out the causes of dyslexia from various perspectives. From a psychological perspective, the term ***developmental dyslexia*** was ignored and ***reading difficulty*** was considered as a kind of spectrum of ***reading retardation*** that ranges from inattentive at one end of the scale to intelligence at the other.

From the educational perspective, educationists were divided into two groups. One group refused to accept the presence of dyslexia while the other group accepted it. The second group thought that

several issues caused dyslexia such as psychological conditions, mental deficit, conducting reading lessons to the child too early or too late, or teaching with faulty techniques. Consequently, the child with dyslexia became a victim and if any treatment was undertaken, it was either by paediatric psychology or, rarely, by remedial teaching (Critchley, 1968).

From the medical perspective, there were two points of view. The first view calculated the number of failures in the eye movement of individuals with dyslexia during their reading. The results revealed that the number of fixation pauses during reading was greater in individuals with dyslexia than individuals without dyslexia (Critchley, 1968). However, the great number of fixation pauses in individuals with dyslexia could be due to their focus on the target word they are trying to read and not due to an impairment in their eye movements.

The second view concentrated on the minimal brain damage that can cause dyslexia. It was commonly thought that the cause of dyslexia was "spastics". Some paediatricians pointed out that minor brain injury during or after birth at the early stage of life caused "developmental dyslexia". While others mentioned that it is caused by cerebral trauma. Neither argument was supported by evidence (Critchley, 1968).

From the sociological perspective, dyslexia has been considered a failure in achieving communication. There were some objections to this argument due to the majority of people with dyslexia who talk fluently from an early stage in their lives (Critchley, 1968). Probably, this argument could be true for some individuals with dyslexia who may have problems in spoken language.

Between 2009 and 2013, there were many attempts to discover the main cause of dyslexia (Sampath et al., 2010) but the main cause of developmental dyslexia is still unknown (Mastropavlou and Zakopoulou, 2013). In fact, it is widely believed that developmental dyslexia is genetic and can be inherited over generations (Walker, 2014; Hamid et al., 2015). Some scientists point out that dyslexia runs in families, as they have found a relationship between a number of genes and issues with reading and processing language (Grigorenko et al., 1997; Walker, 2014; Hamid et al., 2015). On the other hand, acquired dyslexia suddenly affects normal individuals with a standard reading ability after birth usually because of traumatic brain damage (Walker, 2014; Hamid et al., 2015). However, developmental dyslexia occurs more than acquired dyslexia (Rello and Baeza-Yates, 2012) and therefore, developmental dyslexia is adopted by this research.

2.2.3 Symptoms of Dyslexia

Individuals with dyslexia have different symptoms. It is unusual to find two different individuals with dyslexia having exactly the same symptoms (Alsobhi and Abeysinghe, 2013) neither with the same degree nor form of severity of these symptoms (Al-Wabil et al., 2006; Walker, 2014). Therefore, each individual with dyslexia faces different problems in learning. Hence, each individual should

be treated differently to meet their individual needs (Alsobhi and Abeysinghe, 2013).

Individuals with dyslexia face a group of problems and difficulties. For instance:

- ***Reading difficulties***:
  - Adding, deleting, substituting letters of words or words of sentences (WHO, 1992).
  - Reversing letters within a word or words within a sentence (WHO, 1992).
  - Poor word recognition (WHO, 1992).
  - Poor reading fluency (WHO, 1992).
  - Losing place during reading (WHO, 1992).
  - Lower accuracy especially when recognizing and repeating sounds within the words (Walker, 2014).
  - Difficulties in reading multi-syllabic words (Walker, 2014).
  - Difficulties in reading comprehension (WHO, 1992).
- ***Writing and spelling difficulties:***
  - Difficulties and slowness in writing due to spelling errors. However, individuals with dyslexia write single letters at the same pace as their peers (Walker, 2014).
  - Confusion with homophones (words that have the same sound but different spelling) such as the words “there” and “their” (Walker, 2014).
  - Spelling errors and poor decoding abilities (WHO, 1992).
- ***Social and behavioural difficulties:***
  - Avoid getting stressed (Glazzard, 2010).
  - Suffer from depression and anxiety (Walker, 2014).
  - Not participating (Tafti et al., 2009; Glazzard, 2010).
  - Feeling shy (Glazzard, 2010) or isolated (Tafti et al., 2009).
  - Suffer from low levels of self-esteem because of, for instance, peer bullying and teachers’ unfair treatment (Glazzard, 2010).
- ***Other difficulties:***
  - Short-term memory problems (Tafti et al., 2009; Walker, 2014).
  - Calling for both help and reassurance continuously (Glazzard, 2010).

- Problems in expressing ideas in words (Walker, 2014).
- Delay in speech development (Walker, 2014).
- Problems in performing tasks that require phonological awareness. These are tasks that require attention and manipulation of each sound individually (Walker, 2014).
- Problems in remembering, such as remembering names (Walker, 2014).

2.2.4 Developmental Dyslexia Types

Once the educational psychologist, Helmer Myklebust, suggested classifying developmental dyslexia into different types (Friedmann and Coltheart, 2016), various researchers tried to classify dyslexia to deeply understand their difficulties and thus provide suitable support (Alsobhi et al., 2014; Friedmann and Coltheart, 2016). One attempt was by (Annett, 1996) who classified dyslexia for phonology, after conducting three tests: short-term memory for word order, non-word reading and phoneme segmentation into:

- **Phonols**: are left-handed children with dyslexia who have phonological problems by achieving low scores on two or three tests.
- **Non-phonols**: are right-handed children with dyslexia who do not have any phonological problems.

On the other hand, dyslexia was classified based on its symptoms into three groups. This is Ingram's classification (Alsobhi et al., 2014):

- **Visuo-spatial difficulties:** this group is manifested by a difficulty in basic visual processing, weaknesses in visual discrimination (Lovegrove, 1993) and/or visual attentional deficits (Witton et al., 1998). They face these problems:
  - Problems in both differentiating between letters (Alsobhi et al., 2014; Lovegrove, 1993), syllables and phrase orders and in reproducing them.
  - Problems in recognizing letters (Alsobhi et al., 2014; Lovegrove, 1993).
  - Reversals in reading and writing (Alsobhi et al., 2014; Lovegrove, 1993).
  - Confusion between reversible letters such as "b" and "d".
  - Difficulties to follow written instructions (Lovegrove, 1993).
- **Speech sound difficulties:** this group experiences difficulties in understanding spoken language (Alsobhi et al., 2014). In other words, they face difficulty with phonological awareness,

phonological decoding and auditory short-term memory (Bryant and Goswami, 1986). Therefore, they face problems in creating sentences and in breaking words into syllables.

- **Correlating difficulties:** this group faces problems in writing because they are unable to link each letter with its suitable sound especially "monosyllabic" words (words containing only one syllable).

Finally, (Friedmann and Coltheart, 2016) classified dyslexia into ten types using the dual-route model for single-word reading. They suggested predicting the different dyslexia symptoms using this model to determine the different dyslexia types. This model is widely used and has proved effective (Annett, 1996). Consequently, this research adopts that model for dyslexia types. The dual-route model for single-word reading describes the process of reading aloud through different components which, if impaired, will cause a dyslexia type. The reading process is explained in the following sub-section.

2.2.4.1 Dual-route Model for Single-Word Reading

The process of reading aloud a single-word is explained through the dual-route model for single-word reading. This model "*is the result of the work of cognitive neuropsychologists over the past 40 years, including Max Coltheart, John Marshall, Tim Shallice, Karalyn Patterson, Lyndsey Nickels, David Howard, Andrew Ellis, Andrew Young, and others*". There are many models of reading but this model is the best and most straightforward that allows us to determine and predict the various dyslexia types (Friedmann and Haddad-Hanna, 2014). It contains several components where each one performs an essential task in the reading process, as illustrated in Figure 2.1.

The process of reading aloud a single written word via the dual-route model can be summarised in the following stages (Friedmann and Coltheart, 2016):

- Analysing the word using the ***orthographic-visual analysis system*** to identify the letters of the target word, encoding each letter's position within that word, and binding these letters to it by following the sub-stages:

  - *The letter identification sub-stage:* turns the letter into its abstract form by removing its font and size and then identifies only the letter without identifying its name and phoneme.
  - *The letter position sub-stage:* encodes the letter's position within the word with respect to the positions of the first and last letters. Thus, words with similar letters such as the words "clam" and "calm" are read correctly.

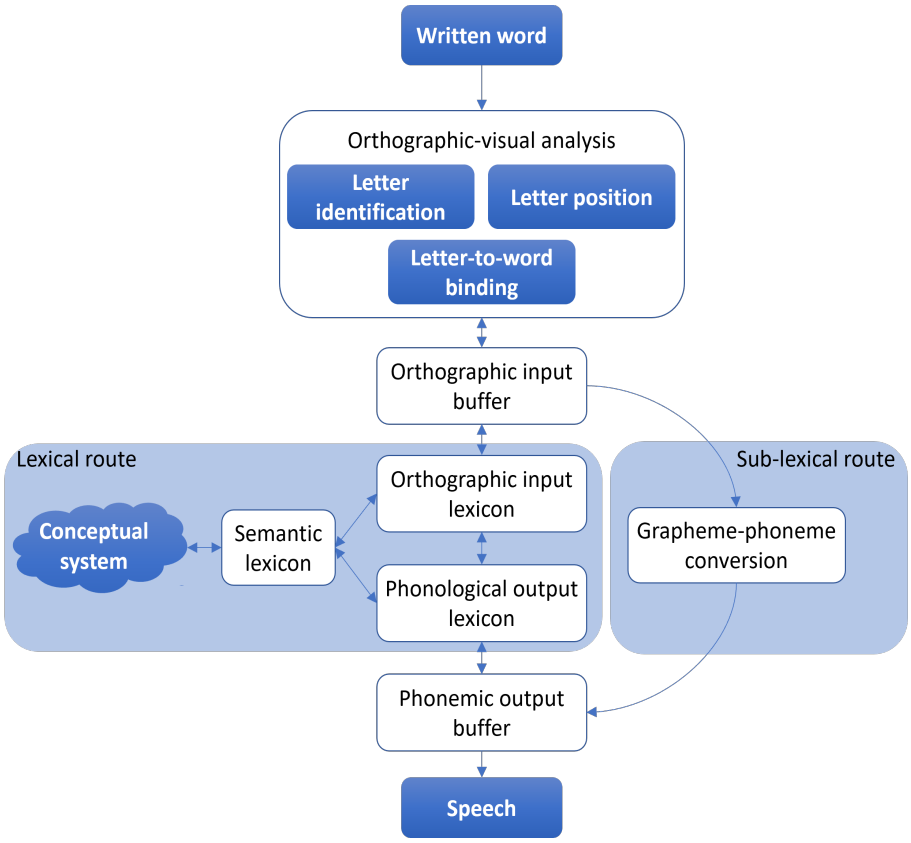


Figure 2.1: Dual-Route Model for Single-Word Reading (Kohnen et al., 2012)

  - *The letter-to-word binding sub-stage:* as the reading process is not about reading a single word but it is about reading a word surrounded by other words, this sub-stage binds the letters to the target word by attenuating the words surrounding that target word.

- Storing the result of the previous stage in short-term memory (***orthographic input buffer***). This memory is also responsible for decomposing the word into its stem and morphological affixes to put it in the appropriate form for the ***orthographic input lexicon*** which stores the words in their stem form. For instance, decomposing the word "birds" into "bird".

- Activating the corresponding entry of the word's stem, resulting from the previous stage, in the ***orthographic input lexicon***, whereas the word's morphological affixes activate their meaning, probably, in the ***phonological output buffer***. For instance, the affix "-s" in the word "birds" indicates a plural meaning.

- Using the lexical route to read known words (that are stored in the reader's lexicon) quickly and accurately by following the stages below:

  - Accessing the ***orthographic input lexicon***. This lexicon stores the known words by listing them depending on their frequency to identify and read aloud frequent words faster than those with low frequency. However, the lexicon does not have the words'

meanings and sounds, but it contains pointers to them.

  - Accessing the written word's phonological form by passing the information to the ***phonological output lexicon***, which contains the phonological information (such as the number of syllables and stress position) of the known spoken words. The conversion from the written word to its sound is performed accurately and quickly due to the direct path connecting the orthographic input lexicon and the phonological output lexicon.
  - Accessing short-term memory named the ***phonological output buffer*** (this is a shared stage with the sub-lexical route that is discussed later). This memory is responsible for two functions: (1) storing the phonological information until its production is completed and (2) grouping its units into larger ones in order to create the whole word. Consequently, the phonological information of the written word is achieved.
  - Activating the corresponding entry of the target word in the ***semantic lexicon*** by the ***orthographic input lexicon*** which in turn activates the corresponding concept in the ***conceptual system*** to achieve the meaning of the target word.

- Using the sub-lexical route to read unfamiliar (unknown) words (words unavailable in the reader's lexicon) or non-words by following the stages:

  - Passing the written word through the ***grapheme-to-phoneme conversion route*** where the letters are analysed into either single letters or group of letters (graphemes) that form a single phoneme. For instance, the letters "c" and "h" in the word "school" are analysed as a single grapheme producing a single phoneme.
  - Accessing the ***phonological output buffer*** to collect the produced phonemes from the previous stage and then grouping them to create a whole new word or non-word.

It is clear that each component in the dual-route model is essential to read aloud successfully. Therefore, a deficit in any of these components negatively affects the reading aloud process and therefore leads to a dyslexia type. Dyslexia has been classified based on the dual-route model into two major categories: **Peripheral Dyslexias** and **Central Dyslexias**.

2.2.4.2 Peripheral Dyslexias

This group of dyslexias face a deficit in the orthographic-visual analysis stage leading to reading impairments. It is further classified into the following types:

Letter Position Dyslexia:

Individuals with letter position dyslexia correctly recognise the letters of the target word but

fail in keeping their positions within the word. Consequently, the letters migrate within the word especially middle ones (Kohnen et al., 2012; Friedmann and Coltheart, 2016; Friedmann et al., 2010) because of lexicality and frequency effects. These migrations occur in (Friedmann and Coltheart, 2016):

- Consonants and vowel letters.
- Root letters and affixes.
- Adjacent letters more than non-adjacent ones.
- Words and non-words especially when the result of the migration is a known word such as "cloud" and "could".

How the migration errors are affected by *lexicality*?

Information about the letters' positions within the target word is obtained from the ***orthographic-visual analysis*** system. If the order of the middle letters is unknown, then an entry that matches this incomplete information will be activated by the ***orthographic input lexicon***. This possibly leads to the cases below:

- If the target word is migratable, for instance, "form", then the incomplete information will be: ("f" as the first letter and "m" as the last one, while the order of the middle letters "o" and "r" is unknown). Therefore, a migration error will occur in the middle letters by activating both "form" and "from".
- If the target word is non-migratable, for instance, "frog", then no migrations in the middle letters will occur because the non-word "forg" does not exist in the ***orthographic input lexicon***.
- If the target word is a non-word and migratable, for instance, "talbe", then, similarly, a migration error in the middle letters will occur by activating the word "table".
- If the target word is a non-word and non-migratable, for instance, "nalbe", then no migrations in the middle letters will occur and thus no entry will be activated in the ***orthographic input lexicon***. So, this non-word will be read by the sub-lexical route, which will provide a better chance to correctly encode the letter order.

How the migration errors are affected by *frequency*?

Migration errors affect low-frequency words more than high-frequency words (Kohnen et al., 2012). For instance (Friedmann and Coltheart, 2016):

- If the target word is, for instance, “salt”, then the incomplete information would be: (“s” as the first letter and “t” as the last one while the order of the middle letters “a” and “l” is unknown). As the word “salt” is more frequently used than “slat”, then it will be activated leading to correct reading.

- If the target word is, for instance, “slat”, and the word “salt” is more frequently used than “slat”, then the word “salt” will be activated leading to incorrect reading due to migration error.

In addition, individuals with letter position dyslexia can omit repeated letters within a word. For instance, reading the word “drivers” as “divers”, because these individuals are unable to encode the position of the middle letters of the word. Thus, they will delete one of the repeated letters. However, it is very rare for migration errors to occur in symbol sequences or numbers (Friedmann and Coltheart, 2016).

In terms of languages, letter position dyslexia can be found in different languages such as Hebrew, English and Arabic. However, it can be diagnosed easily in Hebrew due to the increased number of migratable words that exist in that language. In English, a list of migratable words is required to help in detecting letter position dyslexia. Finally, migrating letters in Arabic is affected by the letters’ positions within the word (Friedmann and Coltheart, 2016). Details on letter position dyslexia in Arabic are presented later in Section 2.3.

Attentional Dyslexia:

Individuals with attentional dyslexia correctly identify both the individual letters of the target word and their positions within that word but fail to bind these letters to their target word. Therefore, migration errors occur between adjacent words instead of within the target word (Friedmann and Coltheart, 2016; Friedmann et al., 2010) as is the case in letter position dyslexia . For instance, reading the pair “cane love” as “lane cove” (Friedmann and Coltheart, 2016).

Additionally, the migrating letters between the words maintain their positions within the words (Friedmann and Coltheart, 2016; Friedmann et al., 2010). For example, the first letter in a word migrates into the first position in the other word. Also, migration between words can occur in all directions: left, right, top or bottom of the target word. The reasons for these migration errors are (Friedmann and Coltheart, 2016):

- The impact of lexicality especially when the result of migration, in both word and non-word pairs, is a known word.

- The words’ length especially between long words.

- The words' similarity especially when the words differ in more than one letter.
- The letters' position, especially the final letter, migrates more than others do. Also, migration from the first to the second word occurs more than the opposite way.

More migration errors can be found in attentional dyslexia. One of these errors is migrating the letter to the other word in the same position, but the letter remains and is not deleted. For example, the pair "light fate" can be read as either "flight late" or "flight fate" without deleting the letter "l" in the first word or the letter "f" in the second one. The other migration error is omitting an instance of a letter if it appears in two adjacent words and in the same position. For instance, reading the words "clay plan" as "clay pan". A possible explanation for this is that individuals with attentional dyslexia fail to bind the letters to their words and several letters appear in the same respective positions in the adjacent words. Therefore, they cannot realise the occurrence of the two instances of a letter and then they delete one of these instances (Friedmann and Coltheart, 2016; Friedmann et al., 2010).

Similarly to letter position dyslexia, attentional dyslexia can be found in various languages such as Hebrew, English and Arabic. It can be easily detected in languages with a high probability of creating known words due to between-word migration. As mentioned in the section on letter position dyslexia, migrating letters in Arabic is affected by the letters' positions within the word (Friedmann and Coltheart, 2016). Details on attentional dyslexia in Arabic are presented later in Section 2.3.

Letter Identity Dyslexia:

Individuals with letter identity dyslexia fail to identify individual letters due to the deficit in the abstract letter identities sub-stage of the ***orthographic-visual analysis*** component. Therefore, they fail to:

- Name a letter.
- Identify both the name and sound of a written letter.
- Match the different cases of a letter such as B and b.

On the other hand, individuals with letter identity dyslexia do not have a visual deficit, so they are able to:

- Match identical non-orthographic forms.
- Match the different sizes of a letter.

- Copy the letters correctly.

Neglect Dyslexia:

Individuals with neglect dyslexia neglect one side (either the left or right) of the target word or sentence depending on the level at which the neglect occurs. Individuals with neglect ***developmental*** dyslexia that have been discussed in the literature, neglect at the word level and it is known as ***neglexia***. They usually neglect the left side of the word by deleting, substituting or adding letters to that side. It occurs more if the result is a known word. Therefore, if a language has a high probability of creating known words after letter substitution, deletion or addition to the word's left side, then more neglect errors will occur. This deficit occurs at the early prelexical stage and therefore it affects the word comprehension and the lexical decision on non-words. Similarly to letter position dyslexia, symbol strings and number sequences are not affected by neglexia as it is orthography-specific and thus affects only letter strings (Friedmann and Coltheart, 2016).

In terms of languages, neglexia is affected by reading direction. So, the beginning of the words will be affected by left neglexia if the language is read from left to right while the end of the words will be affected if the language is read from right to left. In addition, the rate of neglect errors is also affected by the direction of reading. In left neglexia, the rate of errors is more when reading in right-to-left languages than in left-to-right ones. Typically, left neglect has been discovered in languages such as Arabic and Hebrew while right neglect has been discovered in Turkish (Friedmann and Coltheart, 2016).

Visual Dyslexia / Orthographic Input Buffer Dyslexia:

Individuals with visual dyslexia make visual errors in reading (Friedmann et al., 2012). They substitute, migrate, delete and add letters to the target word (Friedmann and Coltheart, 2016; Friedmann et al., 2012) due to a deficit in the output of the orthographic-visual analysis component. Therefore, a combination of all errors discussed earlier can occur (Friedmann and Coltheart, 2016):

- Letter identification errors (Friedmann et al., 2012).
- Letter migrations within and between the words.
- Neglecting one or both sides of the word.

Visual dyslexia differs from the other dyslexia types described above by having a mixture of the previous errors. These errors appear either within a word or between adjacent words. Additionally, unlike letter position dyslexia, the migrations occur in both middle and exterior letters. Visual dyslexia is unlike neglexia by neglecting both sides of the word instead of one side (Friedmann and Coltheart, 2016).

2.2.4.3 Central Dyslexias

This group of dyslexias face a deficit in the last stages of both lexical and sub-lexical routes which also leads to reading impairments. It is further classified into the following types:

Surface Dyslexia:

Individuals with surface dyslexia read aloud via the sub-lexical route (grapheme-to-phoneme conversion) only (Rello and Baeza-Yates, 2012; Friedmann and Coltheart, 2016) because the lexical route is impaired, causing (Friedmann and Coltheart, 2016):

- Errors when reading an irregular word aloud (e.g. stomach) that contains either a silent letter or a letter that is pronounced differently from the sound produced by the grapheme-to-phoneme conversion (Rello and Baeza-Yates, 2012).
- Errors when reading a word aloud that may lead to an ambiguous conversion to phonology. For instance, the word "bear", can be read as "beer".
- Errors when reading multi-syllabic words aloud, especially in languages where the stress is determined lexically and not orthographically. Languages, such as Hebrew and Arabic, that do not use all vowels in the orthography are also affected.

On the other hand, regular words are read correctly using the sub-lexical route because they have only a single pronunciation even if they are rarely used (Friedmann and Coltheart, 2016). Similarly, non-words can be read normally due to the undamaged sub-lexical route (Rello and Baeza-Yates, 2012; Friedmann and Coltheart, 2016).

Besides the affected reading accuracy, surface dyslexia also affects comprehension because this is accomplished by the orthographic input lexicon, which is already impaired. As a result, the sub-lexical route will be used to achieve comprehension. The comprehension of non-homophonic words such as "paper" is achieved correctly while understanding homophonic words (words having the same sound during reading) can be difficult. For instance, the word "wail" cannot be distinguished from "whale" as well as the words "which" and "witch".

Further, surface dyslexia affects reading fluency by slowing the reading process more than normal even if the word is read correctly and accurately via the sub-lexical route. The reason is that each letter in the target word should be converted into its phoneme sequentially rather than reading it as a whole via the lexical route.

Since the lexical route contains multiple components, then a deficit in any of these components or in their connections will lead to surface dyslexia that affects reading accuracy and fluency. Besides

these effects, more difficulties may arise depending on the affected component as detailed below:

- Either the orthographic input lexicon or accessing it via the orthographic-visual analyser is harmed. Therefore, the lexical decision of pseudohomophones is affected. For instance, difficult in deciding if "anser" is a word or not. Also, understanding homophones and potentiophones is affected. For instance, difficult in deciding if the word "whether" is a question or is explaining things like rain and temperature.

- The connection from the output of the orthographic input lexicon to the semantic lexicon and the phonological output lexicon is impaired. Thus, the lexical decision is intact but the homophone comprehension is affected.

- Inter-lexical surface dyslexia, where the deficit is located in the connection between the orthographic input lexicon and the phonological output lexicon. Thus, the lexical decision and the homophone comprehension are intact but reading aloud is affected.

- The phonological output lexicon itself is impaired which causes a deficit in word production in the context of reading, naming and casual speech.

Phonological Dyslexia:

Individuals with phonological dyslexia correctly read words that are stored in the orthographic input lexicon and phonological output lexicon while misreading non-words. This is due to a deficit at various points of the sub-lexical route. Therefore, leaving the lexical route to proceed with the reading by itself (Friedmann and Coltheart, 2016; Khentov-Kraus and Friedmann, 2018). This, in turn, causes individuals with phonological dyslexia to be unable to read new words. Consequently, this causes a problem for children with this type of dyslexia when they begin to read. These children consider each written word as a new word and so they are unable to access the lexical route. Thus, they need a long time to learn to read and they master their reading after storing an appropriate number of words in their orthographic input lexicon. They, also, face difficulties when learning to read new languages (Friedmann and Coltheart, 2016).

According to (Friedmann and Coltheart, 2016), phonological dyslexia can be categorised based on the deficit type in the sub-lexical route into:

- *Letter-to-phoneme conversion phonological dyslexia:* Individuals with such dyslexia face difficulty in converting single letters into their phonemes. Thus, reading single letters (alongside non-words) is impaired and pronouncing them is difficult.

- *Multi-letter phonological dyslexia:* Individuals with such dyslexia face difficulty in converting multiple letters into their phonemes. For instance, facing difficulty in pronouncing the "sh" in "ship" and "ch" in "chip". Such individuals face difficulty in reading multi-letter graphemes and not single letters.

- *Phonological-output-buffer-phonological-dyslexia:* This is the most frequent type of phonological dyslexia. Individuals with such dyslexia face difficulty in reading long words and non-words. So, they produce errors in long words more than in short ones. This is caused by a deficit in the phonological output buffer after the conversion process. This buffer, as mentioned before, is responsible for receiving the output of the conversion process, collecting and maintaining it until the result is completed. In addition, non-words are affected more than the words that are supported by activating the phonological output lexicon. As the phonological output buffer is also responsible for collecting morphologically complex words, then individuals with such phonological dyslexia misread these words by either deleting or replacing the non-base parts. Lastly, since the speech production system also contains the phonological output buffer, then repeating or saying non-words and morphologically complex ones is also affected.

Vowel Letter Dyslexia:

Individuals with vowel letter dyslexia omit, migrate, substitute and add vowel letters (such as reading the word "bit" as "but" or "boat") due to a specific deficit in the sub-lexical route that is responsible for processing vowels. Such errors appear only in the vowel letters during reading and not in the vowel phonemes during speech production (Khentov-Kraus and Friedmann, 2018; Friedmann and Coltheart, 2016). The most frequent vowel error type reported by (Khentov-Kraus and Friedmann, 2018) is vowel migrations whereas vowel substitutions were the least frequent ones which result from vowel omissions and additions.

Since the deficit is in the sub-lexical route, then individuals with vowel letter dyslexia will have problems only in reading new and non-words and they do not face problems in reading known words through the lexical route. As with the previous dyslexia types, the errors occur more frequently if they result in a known word (Khentov-Kraus and Friedmann, 2018; Friedmann and Coltheart, 2016).

In terms of languages, vowel letter dyslexia has been identified in several languages such as Arabic and Hebrew. In such languages, this deficit is obvious because of the existence of vowel letter omissions or transpositions in the orthographies (Friedmann and Coltheart, 2016).

Unlike letter position dyslexia, vowel letter dyslexia is not affected by the letter's form. Because

the deficit is in the grapheme-to-phoneme conversion stage which is not sensitive to the letter's form. Therefore, vowel errors occur whether the letter's form is changed or not (Friedmann and Coltheart, 2016).

Deep Dyslexia:

Individuals with deep dyslexia produce the following errors (Friedmann and Coltheart, 2016):

- Semantic errors (Khentov-Kraus and Friedmann, 2018). For instance, reading the word "lime" as "lemon".
- Morphological errors. For instance, reading the word "played" as "play".
- Visual errors. For instance, reading the word "owl" as "own".

The cause of deep dyslexia is the damage in both the lexical route between the orthographic input lexicon and the phonological output lexicon and the sub-lexical (grapheme-to-phoneme conversion) route. Essentially, individuals with deep dyslexia can accurately read the words that have a visual image by reading via their meaning. However, they have reading problems based on the types of words, as follows:

- Non-words either cannot be read or can be read as a similar known word. For example, reading "diger" as "tiger".
- Function and abstract words either cannot be read or can be read as another function or visually similar concrete word. This means that concrete words are read better than abstract ones.
- Morphologically complex words are difficult to read. Morphological affixes are either replaced or deleted from such words due to the image-ability effect. For instance, trying to imagine the word "opened" visually may lead to deleting the suffix "-ed". More precisely, the words are searched through the lexicon by their stems while the morphological affixes are read using a direct route to the phonological output buffer from the orthographic input buffer. However, this route is impaired so the stems are read better than affixes. Therefore, languages with more morphologically complex words will be more difficult to read.

In terms of languages, deep dyslexia can be found in both English and Arabic. However, Arabic was identified as a diglossic language where the spoken language is different from the written, standard one. Consequently, individuals with deep dyslexia read a word by looking into it, understanding it and then naming it based on its meaning. Therefore, reading the word as a spoken vernacular

rather than the standard way it was written. For instance, reading the standard Arabic word "tabib" which means medical doctor as its spoken language "daktor".

Access To Semantics Dyslexia:

Individuals with access to semantics dyslexia (also known as "***direct dyslexia***") can read accurately and fluently. They can read aloud all types of words such as irregular, function, low frequency and morphologically complex ones. They can also accurately read non-words and new words.

Despite, the ability of individuals with access to semantics dyslexia to read aloud correctly, they cannot understand these written words. This signals that both the lexical and sub-lexical routes are preserved. So, one of the following deficits can cause this problem:

- A deficit in accessing the semantic lexicon from the orthographic input lexicon due to the disconnection between them. This disconnection affects only the understanding of written words, which means that reading aloud of both single words and non-words, understanding heard words and producing words are not affected.
- A deficit in the conceptual or semantic system itself. If this is the case, then it will be called "semantic deficit" and not "dyslexia". Such individuals misunderstand both words they hear and read.

2.2.5 Summary

Dyslexia is a specific learning difficulty that primarily affects individuals' ability to read. It is widely believed that dyslexia is neurological in origin. There have been various attempts to define dyslexia but there is still no formal definition that is universally accepted and generalised. Dyslexia can be caused by either inheritance and known as "developmental dyslexia" or trauma and known as "acquired dyslexia". Since the number of individuals with acquired dyslexia is small, then this research is focused on developmental dyslexia .

There are different symptoms that identify dyslexia. It is unusual to find two individuals with dyslexia with the same symptoms. Essentially, individuals with dyslexia face a variety of reading difficulties such as adding, deleting, migrating or substituting letters of words or words of sentences. Other difficulties may co-occur with dyslexia such as writing, spelling and behavioural difficulties. On the other hand, some researchers pointed out that individuals with dyslexia may perform well in other aspects such as being creative and able to solve problems.

Many researchers have classified dyslexia into different types to understand their difficulties and thus provide them with suitable support. (Friedmann and Coltheart, 2016) classified dyslexia into ten different types based on the affected component of the dual-route model for single-word reading. For instance, letter position dyslexia, vowel letter dyslexia and visual dyslexia. Dyslexia is affected

by the language's structure and orthography, therefore its symptoms and types will also be affected. Since this research targets Arabic, then dyslexia in Arabic is discussed in the next section.

2.3 Dyslexia in Arabic

The Arabic language is the fifth most spoken language in the world in terms of the number of native speakers. Over 200 million individuals, especially in the Middle East and North Africa, speak Arabic as their first language. In addition, Arabic is used as a second language by millions of Muslims because it is the language of the Holy Quran (Mahfoudhi et al., 2011).

Unfortunately, there are very few studies that have explored dyslexia in Arabic. Consequently, this research focuses on learners with Arabic dyslexia. There are, also, some Arab countries that do not pay attention to children with dyslexia in schools, such as Morocco (El Kah and Lakhouaja, 2015). (El Kah and Lakhouaja, 2015) have made a survey in three different cities of Morocco about both learning disabled children and Arabic language learning difficulties. In this study, 86 teachers and 2,304 students participated in order to gather the common mistakes encountered among the students during their learning of Arabic, based on teachers' experiences. The different reasons for the low academic achievement were considered. The results revealed that half of the teachers lack knowledge about learning difficulties while the other half have little information about them. None of them attended any training in special education. Therefore, such teachers should better understand learning difficulties in terms of symptoms and consequences.

As the Arabic orthography is different from that of English, it affects individuals with dyslexia differently. Different factors may contribute to the manifestation of Arabic dyslexia; unique Arabic features and cultural characteristics (AlRowais et al., 2013). Therefore, the following subsections will present in detail the Arabic orthography, cultural factors that affect Arabic, Arabic features that contribute to the manifestation of dyslexia and the classification of developmental Arabic dyslexia types.

2.3.1 Arabic Orthography

The Arabic language, like all languages, has many features. Some of those features are listed below:

- It is an alphabetic system (Elbeheri et al., 2006; Béland and Mimouni, 2001) that contains 28 letters (Elbeheri et al., 2006; Béland and Mimouni, 2001; Friedmann and Haddad-Hanna, 2014) representing 34 phonemes (Elbeheri et al., 2006; Mahfoudhi et al., 2011). All of these letters are consonants with some of them providing long vowels (Abu-Rabia, 1998) which are (a, i, u) (و، ي، ا) (Friedmann and Haddad-Hanna, 2014). These letters are originally made from 17 different shapes with dots added to them and placed either above or below (Elbeheri et al., 2006; Elbeheri, 2005). These dots are important and differ in their position

(above/below the character) and number (one, two or three) (Elbeheri et al., 2006) (See Figure 2.2).

- Lower and upper cases are not available in Arabic so the shape of these letters is consistent (AlRowais et al., 2013; Elbeheri et al., 2006; Béland and Mimouni, 2001).

- It is a bidirectional script because it is read and written in both directions where the text is right-left and the numbers are left-right (AlRowais et al., 2013; Elbeheri et al., 2006; Béland and Mimouni, 2001) (See Figure 2.3).

- It uses short vowels known as diacritics as listed in Table 2.1. They are not considered as independent graphemes (Elbeheri et al., 2006; Béland and Mimouni, 2001; Mahfoudhi et al., 2011; Elbeheri, 2005; Friedmann and Haddad-Hanna, 2014) and are usually used in the Holy Quran, poetry, children's books, early years teaching materials used for reading and writing skills, etc. (Elbeheri et al., 2006; Béland and Mimouni, 2001; Mahfoudhi et al., 2011). However, they are eliminated from the written text once the child begins to master reading and writing skills (Béland and Mimouni, 2001; Mahfoudhi et al., 2011).

- It is a Semitic language with a rich morphological structure in both nouns and verbs. Most of these nouns and verbs are constructed from three-consonant roots that are incorporated in verbal or nominal templates (Friedmann and Haddad-Hanna, 2014). In Semitic languages, most nouns and verbs are derived from a root and a word pattern named a template. The root and the template are unpronounceable bound morphemes on their own. The skeleton of consonants is represented by the root to provide the core meaning, or the semantic family which is inserted into the template to produce "a unique lexical item with a unique meaning and a well-defined grammatical category directly discernible by the specific word pattern" (Saiegh-Haddad and Henkin-Roitfarb, 2014, p. 9).

- It is special in its transparency. Transparency indicates the relationship between letters and sounds. If there is a simple one-to-one relationship then this language is said to be transparent while the language is less transparent (such as English) once the relationship becomes more complex (Elbeheri et al., 2006; Béland and Mimouni, 2001; Mahfoudhi et al., 2011; Al-Wabil et al., 2006). In the case of Arabic, the diacritics are used to produce a vowelised text (shallow orthography) by using short vowels (above or below the letter (Abu-Rabia, 1998)) in the beginner readers' texts. In more advanced written texts, these diacritics are eliminated to produce non-vowelised texts (deep orthography) (Elbeheri et al., 2006; Mahfoudhi et al., 2011; Elbeheri, 2005). Thus, creating highly ambiguous text by producing homographs (Elbeheri

et al., 2006; Mahfoudhi et al., 2011; Elbeheri, 2005) (words containing the same letters but with different pronunciations and meanings (Béland and Mimouni, 2001; Abu-Rabia, 1998)). These homographs can be pronounced and understood correctly either with diacritics (Béland and Mimouni, 2001; Abu-Rabia, 1998) or via using the context in which they are included (Elbeheri et al., 2006; Béland and Mimouni, 2001; Mahfoudhi et al., 2011; Elbeheri, 2005) (See Figure 2.4). Further, the effect of vowels in Arabic orthography on reading accuracy has been investigated by (Abu-Rabia, 1998) and on reading comprehension by (Abu-Rabia, 2001). He found that diacritics have a significant impact on reading accuracy for both poor and skilled Arabic readers and they affect both the silent reading comprehension and word recognition whether it is isolated or within a context.

- It is a cursive language (Elbeheri et al., 2006; Friedmann and Haddad-Hanna, 2014) because letters making up the word are connected by ligatures leading these connected letters to change their shapes from their isolated original form (Elbeheri et al., 2006). The letters can have up to four different shapes based on their position within a word (beginning, middle, end or isolated shape) (Elbeheri et al., 2006; Béland and Mimouni, 2001; Elbeheri, 2005; Abu-Rabia, 1998, 2001; Friedmann and Haddad-Hanna, 2014) (See Figure 2.5). Twenty-two of them can be connected from both sides by joining to both preceding and following letters leading them to form all the four shapes (Elbeheri et al., 2006). The other six letters can only be connected from one side by joining to only the preceding letter leading them to form only two different shapes (end or isolated shape) (Elbeheri et al., 2006; Friedmann and Haddad-Hanna, 2014). Those six letters are: ا، ذ، د، ز، ر، و (Friedmann and Haddad-Hanna, 2014).

- Spaces between words can be used as word boundaries. However, the existence of one or more of the six letters (explained in the previous point) may lead to breaking a single-word into sub-words forming additional spaces within the word. Therefore, identifying the word boundaries can be difficult for beginners (Elbeheri et al., 2006) (See Figure 2.6).

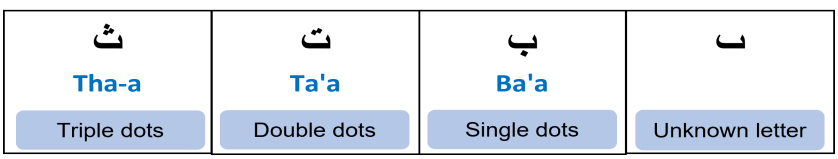


Figure 2.2: Different Arabic Letters with Similar Shape and Different Number and Position of Dots

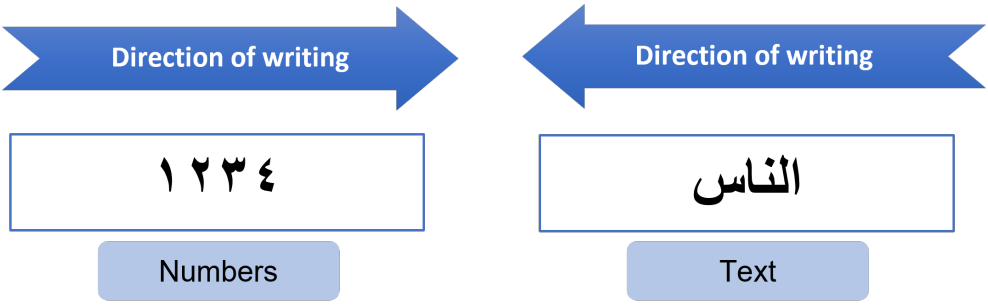


Figure 2.3: Direction of Arabic Writing

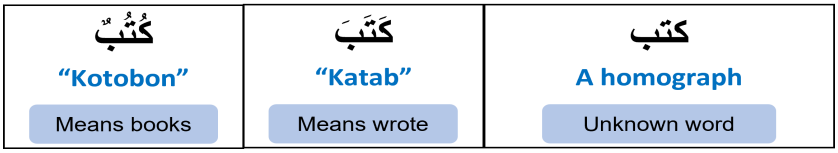


Figure 2.4: A Homograph with Different Diacritics

Table 2.1: Arabic Short Vowels

Vowel	Name	Position	Example
أَ	Fat-ha	Above the letter	مَدرسة
أُ	Dammah	Above the letter	مُعلمة
أّ	Shaddah	Above the letter	معلّمة
أْ	Sukun	Above the letter	بيْت
أً	Tanween - Fat-h	Above the letter	بيتاً
أٌ	Tanween - Dam	Above the letter	بيتٌ
إِ	Kasrah	Below the letter	جِمال
إٍ	Tanween - Kasr	Below the letter	بيتٍ

2.3.2 Cultural Factors

Language can be seen as a cultural trait that may define a cultural group. Therefore, a language can be influenced by many cultural factors. One such cultural factor that has a significant impact on dyslexia is dialects of the language (AlRowais et al., 2013) within the culture known as ***diglossia*** (Mahfoudhi et al., 2011; Friedmann and Haddad-Hanna, 2014).

Diglossia is an important feature in Arabic that should be considered. This feature means using two versions of the language within a community: Spoken Arabic Language and Modern Standard Language (Mahfoudhi et al., 2011):

- **Spoken Arabic Language**: is the language that is used every day and the first language that is learned by the Arabic speaking child (Mahfoudhi et al., 2011). It is one of the Arabic dialects that is spoken across a country or within a specific region (Mahfoudhi et al., 2011; Abu-Rabia et al., 2003; Friedmann and Haddad-Hanna, 2014).

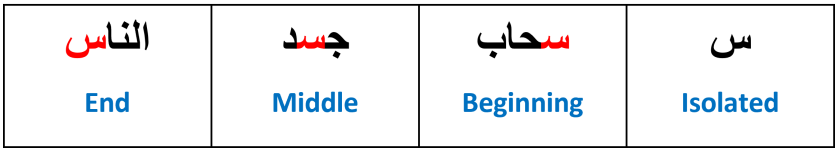


Figure 2.5: Different Shapes of Arabic Letter "**Seen**"

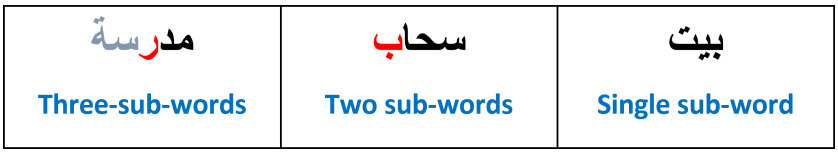


Figure 2.6: Different Words with Different Number of Sub-Words

- **Modern Standard Language**: is the classical Arabic form that differs from the Spoken Arabic Language in terms of lexical items, syntax, morphology, and phonology (Mahfoudhi et al., 2011; Friedmann and Haddad-Hanna, 2014). It is also known as ***Literary Arabic*** (Abu-Rabia et al., 2003). This form is used in both education and media, in writing and speaking. Therefore, it is considered the prestigious form of Arabic. Usually, this kind is not taught and used by children until they enter school. Therefore, teaching Literary Arabic to children at school can be considered as teaching them a second language (Abu-Rabia et al., 2003; Friedmann and Haddad-Hanna, 2014).

2.3.3 Dyslexia and Arabic

Many Arabic features can be partially responsible for the manifestation of dyslexia such as (Elbeheri, 2005):

- The cursive nature of Arabic where the letters are joined to form a word or sub-word.
- Using dots to distinguish between different letters.
- Different letter shapes that depend on its position within the word.
- Using the deep orthography which is a text that eliminates the diacritical marks (Elbeheri, 2005). Reading Arabic script without diacritics is a difficult process for beginners and poor readers (Abu-Rabia et al., 2003), such as individuals with dyslexia. However, this issue is not present in English because the vowels are presented explicitly using letters (Al-Wabil et al., 2006; Abu-Rabia, 1998). For instance, consider the English words "herd", "hired", "hard", and "heard". By using a deep orthography in the Arabic text, then these words will be written as "hrd" and then the reader will be responsible for decoding the word and identifying its missing short vowels depending on the context. Moreover, using deep orthography in Arabic electronic content may affect screen readers because they might mispronounce the words

and therefore misunderstand the content. In addition, the dyslexia group will be forced to read without diacritics, leading them to combine contextualised cognition and visual memory, adding more load to their cognitive burden (Al-Wabil et al., 2006).

A study conducted by (Abu-Rabia et al., 2003) investigated the ***word identification processes*** (phonological decoding and orthographic processing) in Arabic and ***basic cognitive processes*** (syntactic and morphological awareness, working memory, and visual processing) among readers with dyslexia, normal readers of the same chronological age and normal readers at the same reading level. Readers with dyslexia have been compared with these normal readers using a series of tests developed in Arabic and derived from the ones available in both English and Hebrew languages. Several findings were revealed among the dyslexia group:

- **In terms of word identification processes:**
  - Deficiencies in phonological decoding.
  - Strengths in orthographic processing because their reading strategy was through the visual-orthographic route and not through the phonological route. Due to the orthographic nature of Arabic, the visual-orthographic route access is considered the most effective reading strategy.
- **In terms of basic cognitive processes:**
  - Significant deficiencies in syntactic skills. However, their performance is better than normal readers of the same reading level on the oral test but poorer than both normal reader groups on the grammatical judgement test.
  - Significant deficiencies in morphological measures and working memory skills.
  - Severe deficiencies in phonological awareness due to the lack of exposure to Modern Standard Language at home because parents consider it as a second language.

2.3.4 Developmental Arabic Dyslexia Types

Developmental dyslexia comprises different forms. There are ten types of developmental dyslexia in the literature, based on the type of deficit in the dual-route model for single-word reading which was discussed earlier in Section 2.2.4.1. In Arabic, developmental dyslexia is classified into seven types grouped into peripheral dyslexias and central dyslexias. **Peripheral dyslexias** contains letter position dyslexia, attentional dyslexia, visual dyslexia and neglect dyslexia, while **central dyslexias** contains surface dyslexia, vowel letter dyslexia and deep dyslexia. Some of them affect

the reading of individuals with dyslexia at the word level while others affect them at the sentence level (see Figure 2.7).

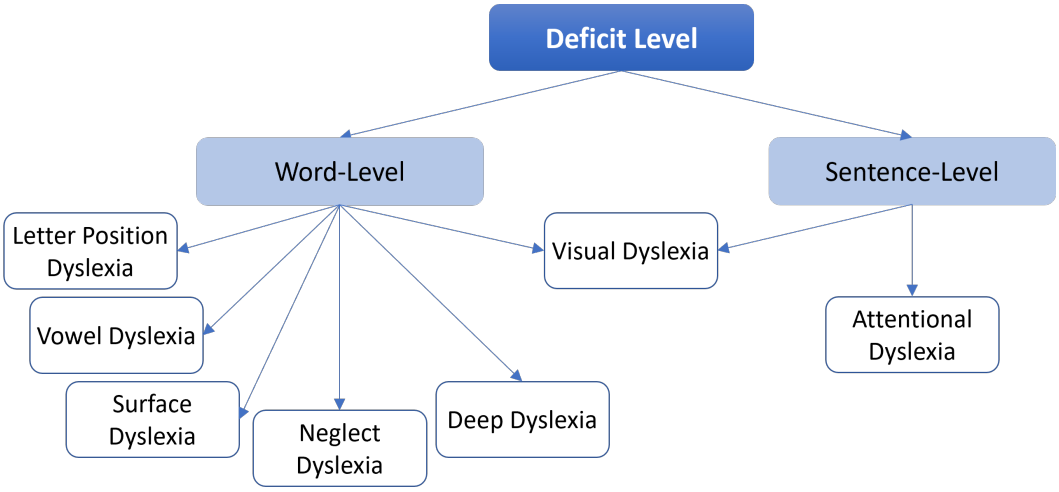


Figure 2.7: Deficit Level of Developmental Arabic Dyslexia

The differences between individuals with dyslexia are due to (Friedmann and Haddad-Hanna, 2014):

- The part of the reading process that is affected.
- The properties of the language's orthography. For instance, the dyslexia type that causes individuals to read by the sub-lexical route may cause more difficulty in the Arabic orthography due to the elimination of short vowels which results in different ways of reading.

2.3.4.1 Peripheral Dyslexias

Peripheral dyslexia types result from deficiencies in the orthographic-visual analysis component (Friedmann and Haddad-Hanna, 2014).

Developmental Letter Position Dyslexia:

Letter position dyslexia is letter position errors in reading caused by a reading deficit in the orthographic-visual analyser stage, specifically the function that is responsible for encoding the relative position of letters within the word. This dyslexia type migrates the letters within words, precisely the middle letters, especially when the result is another known word and is used frequently (Friedmann and Haddad-Hanna, 2014, 2012).

In Arabic, there are plenty of migratable words due to the nature of both the Arabic orthography and its Semitic morphology. In terms of ***Arabic orthography***, short vowels are usually not used in the Arabic script leading to a degree of freedom in reading. In other words, letter migrations may lead to letter combinations that can be read in different ways, which often matches another known word. In terms of ***Arabic Semitic morphology***, a large number of migratable words can

be generated from a consonantal root and a template resulting in many word pairs. According to (Friedmann and Haddad-Hanna, 2014), these word pairs can result from:

- Changing the root consonants' order with the same template. For example, the word pair "يعملون" which is pronounced as "Ya'amaloon" and means "work - masculine plural" and "يعلمون" which is pronounced as "Ya'alamoon" and means "know - masculine plural".
- Changing the template (may differ only in the middle letters' position) with the same root. For example, the word pair "كتاب" which is pronounced as "ketab" and means "book" and "كاتب" which is pronounced as "kateb" and means "writer".

Based on these considerations, letter position dyslexia tends to cause more errors in Arabic and therefore will be more easily detected than in English where usually a non-word results from a migration of the middle letters (Friedmann and Haddad-Hanna, 2014).
In contrast, the letter forms that depend on the letter's position within the word lead to a lower rate of migrations within words than in other languages because (Friedmann and Haddad-Hanna, 2014, 2012):

- A letter position error may create another known word while preserving the letter's form with a different position. For instance, the words "تمهل" which is pronounced as "tamahhal" and means "slow down" and "تهمل" which is pronounced as "tohmil" and means "ignore".
- A letter position error may create another known word while changing the letter's form when changing its position. For instance, the words "جهاز" which is pronounced as "jehaz" and means "device" and "جاهز" which is pronounced as "jahez" and means "ready".

The last issue may lead to migrating the letters without changing their original form and thus creating an orthographically illegal sequence in all common Arabic fonts. For instance, changing, the previous words from "جهاز" to "جـاـهز" is illegal. Therefore, when considering the letter's form then fewer words will be legal and accepted after letter migration (Friedmann and Haddad-Hanna, 2014, 2012). These two issues have been studied by (Friedmann and Haddad-Hanna, 2014) on third to fourth-grade children with dyslexia to check if they have letter position dyslexia or not. It has been found that all participants presented the same results. They lead to making fewer letter position errors if the resultant word causes a change in the letter's form than if it does not change. Therefore, migrations are likely to occur less if the resultant word has an illegal orthographic sequence.

Developmental Attentional Dyslexia:

As mentioned in Section 2.2.4.2, developmental attentional dyslexia is a reading deficit that has one or more of the following problems (Friedmann and Haddad-Hanna, 2014; Friedmann et al., 2010; Friedmann and Coltheart, 2016):

- The letters are correctly identified but they migrate between words preserving their correct relative position within the word. For example, reading the words "goat" and "coal", as "goal" and "coal".
- One of the instances of a letter that appears in the same position in both words is deleted. For example, in the words "goat" and "coal", the letter "a" can be deleted and thus read these words as "got" and "coal".
- The letters are migrated from a word that does not exist anymore in the visual field, instead it is in the orthographic buffer, to the corresponding position of the target word without deleting the original letter in that position. This type of error is known as ***buffer migration***. However, this issue occurs less frequently than the previous two.

In addition, migrations can appear horizontally (from words that appear right and left of the target word) and vertically (from words that appear above and below the target word). Again, as in letter position dyslexia, the error rate increases if the result of the migration is a known word (Friedmann and Haddad-Hanna, 2014).

In Arabic, due to the elimination of diacritics and the Semitic morphological structure, the position-preserving migrations between words may often create other known words. However, the form of the letter can affect this type of migration in the opposite direction. As described in letter position dyslexia, the forms of a letter reduce the rate of between-word migrations in Arabic when compared with other languages, because any change in the form of the letter blocks migrations. Further, because the migrations between the words usually occur in the final letters and such migrations may change the form of the letter, then these migrations are blocked (Friedmann and Haddad-Hanna, 2014).

The rate of this dyslexia type is low based on the results of the study conducted by (Friedmann and Haddad-Hanna, 2014) that was tested on 74 participants and found that only two had attentional dyslexia with one of them also having other dyslexia types.

Developmental Visual Dyslexia:

Visual dyslexia is a visual error in reading caused by a reading deficit in the orthographic-visual analysis stage (Friedmann and Haddad-Hanna, 2014). A visual error can involve additions, substi-

tutions and omissions of letters and appears when at least half of the letters in the target word are available in the error response (Friedmann and Haddad-Hanna, 2014). Further, this visual error cannot be accounted for by a deficit in a specific component of the orthographic-visual analyser. Thus, this type is different from the other dyslexia types that suffer from a deficit in a specific component of the orthographic-visual analyser such as letter position dyslexia and attentional dyslexia (Friedmann and Haddad-Hanna, 2014). For instance, if an individual usually makes letter migrations, then this will be defined more specifically as an letter position dyslexia and not as visual dyslexia even if half of the letters of the target word were available in the error response (Friedmann and Haddad-Hanna, 2014).

In addition, visual dyslexia can result from a deficit in either the orthographic-visual analysis system that selectively impairs the ability to encode abstract letter identity or the output of the orthographic-visual analyser (Friedmann and Haddad-Hanna, 2014).

In the study conducted by (Friedmann and Haddad-Hanna, 2014), six of the participants had visual dyslexia, especially the one that results from a deficit in the output of the orthographic-visual analyser. This is because the error types that they made during reading aloud were substitutions, omissions, additions and migrations of the letters within the words and between the words. Also, they did not have any tendency to produce errors on one specific side of the words. Unlike letter position dyslexia, it has been found in visual dyslexia that letter migrations do not necessarily preserve their within-word position and thus may occur in first and last letters of the word.

Developmental Neglect Dyslexia:

Developmental neglect dyslexia (also known as ***neglexia***) is a reading deficit at the word level that results in neglecting one side of the word, typically the left side of it. This means that letter omissions, substitutions, or additions occur on that side of the word (Friedmann and Haddad-Hanna, 2014). Further, the reading direction typically affects the part of the word that will be neglected. Since Arabic is read from right to left, and because neglexia usually neglects the left side of the words, then the end of the Arabic word will be affected rather than the beginning (Friedmann and Haddad-Hanna, 2014).

2.3.4.2 Central Dyslexias

The following central dyslexia types result from deficiencies in the later stages of the reading process, precisely the lexical and sub-lexical routes (Friedmann and Haddad-Hanna, 2014).

Developmental Surface Dyslexia:

Developmental surface dyslexia results from a deficit in the lexical route (that links the orthographic input lexicon with the phonological output lexicon) leading to reading by the sub-lexical route (grapheme-to-phoneme conversion route) (Friedmann and Haddad-Hanna, 2014; Friedmann and

Lukov, 2008). Therefore, leading to the characteristics below (Friedmann and Haddad-Hanna, 2014):

- Incorrectly reading irregular words such as "listen" because for these words to be read accurately requires the word-specific knowledge that is available in the orthographic input lexicon which can be accessed only by the lexical route (the affected route).
- Correctly reading regular words by the sub-lexical route but the reading rate is affected, leading to slow reading.
- Correctly reading non-words by the sub-lexical route.
- Reading comprehension is affected due to the impairment in the orthographic input lexicon. Therefore, homophones will be indistinguishable for individuals with surface dyslexia (Friedmann and Lukov, 2008).

In Arabic, specifically in the Modern Standard Language orthography, there are almost no homophonic letters (i.e. letters sound the same (Saiegh-Haddad and Joshi, 2014, p. 139)) which reduces the error rate for reading even if the reading was by the sub-lexical route. Unfortunately, and due to the absence of short vowels in the Arabic orthography, an individual with surface dyslexia will have to guess the appropriate vowels for the target word. This issue in Arabic is known as ***irregularity*** which leads to reading the target word in different ways. For instance, the word "فتحة" can be read as either "fat-ha" which is a short vowel or "fataha" which means "he opened" and written as "فتح". Another form of irregularity occurs with words ending with "وا" such as the word "عملوا". This combination of letters produces irregularity because it stands for the masculine plural ending of the past tense verbs and is pronounced as the long vowel "u" instead of "wa" (Friedmann and Haddad-Hanna, 2014).

Finally, other frequent errors that were made by individuals with surface dyslexia were related to the conversion of special orthographic symbols (Friedmann and Haddad-Hanna, 2014) such as:

- Shadda "ّا", which indicates doubling the consonant .
- Hamza "ء", which indicates a glottal stop and appears either alone or with a vowel.
- Tanwin fat-h "اً", which appears as a double fat-ha (the diacritic mark for the vowel "a") but requires pronouncing an "n" sound, that is not written explicitly. It is sometimes followed by alif "ا".

- Taa marboutah "ة", which appears at the end of the word and sounds like either fat-ha (short a) in an un-vowelised Arabic text, or "t" in a construct state nominal when it appears at the end of the first word.

- Alef maqsuoora "ى", which appears at the end of a word and is written as the letter "ي" without the dots. It is a short ***a*** sound, for example, the word "مستشفى" which is a hospital.

Developmental Vowel Dyslexia:

Vowel letter dyslexia, unlike developmental surface dyslexia, results from a deficit in the sub-lexical route, which precisely impairs the way the vowels are being processed by that route (Friedmann and Haddad-Hanna, 2014). Therefore, individuals with vowel letter dyslexia substitute, omit, transpose and add vowel letters such as reading the English word "bug" as "big". In addition, if an individual has only vowel letter dyslexia then non-words, which are read via the sub-lexical route, will be the only ones affected while, on the other hand, if an individual has both vowel letter dyslexia and surface dyslexia then both known words and non-words will be affected because the known words will be read by the sub-lexical route (Friedmann and Haddad-Hanna, 2014).

In the Arabic orthography, three aspects should be considered (Friedmann and Haddad-Hanna, 2014):

- Each vowel letter identifies a single long vowel.

- There is a difference between long and short vowels. Long vowels are encoded orthographically while short ones are represented using diacritics and usually eliminated from the written words.

- Vowel letters have different forms, as detailed before, depending on their position.

Vowel letter dyslexia occurs more frequently among learners with Arabic dyslexia based on the study run by (Friedmann and Haddad-Hanna, 2014). All participants with vowel letter dyslexia made more errors in vowel letters than in consonants. These vowel errors were vowel additions, migrations, omissions and substitutions. Vowel addition is indicated by the elongation of a short vowel while vowel omission is indicated by shortening a long vowel.

Further, Arabic participants made errors whether the vowel letter performs as a consonant or as a vowel. This is because they read by the sub-lexical route that does not have any information about the function of a vowel letter in a certain word (Friedmann and Haddad-Hanna, 2014).

Finally, vowel migrations, that result from vowel letter dyslexia, appear even if the resultant word changed the vowel letter's form. In fact, this contrasts with letter position dyslexia which blocks

the letter migration if it results in changing the letter's form. This feature enables discrimination between vowel letter dyslexia and letter position dyslexia (Friedmann and Haddad-Hanna, 2014).

Developmental Deep Dyslexia:

Developmental deep dyslexia faces a number of difficulties (Friedmann and Haddad-Hanna, 2014; Johnston, 1983):

- Semantic, morphological and visual errors in reading.
- Severe deficit in reading function words by either reading them as another function word or inability to read them.
- Inability to read non-words.

However, developmental deep dyslexia can better read (Friedmann and Haddad-Hanna, 2014):

- Nouns than verbs and adjectives.
- Concrete words than abstract ones.

These characteristics of deep dyslexia are due to multiple deficits; one is in the sub-lexical (grapheme-to-phoneme conversion) route and the other is in the lexical route between the orthographic input lexicon and the phonological output lexicon. Therefore, forcing the individual with dyslexia to read by meaning (Friedmann and Haddad-Hanna, 2014).

In Arabic, two properties should be considered to identify deep dyslexia (Friedmann and Haddad-Hanna, 2014):

- **Diglossia**: this property affects individuals with deep dyslexia due to the differences between the written Modern Standard Language and Spoken Arabic Language (dialects) in terms of phonology, lexicon, and syntax. As reading by meaning characterises deep dyslexia, this may lead such individuals to read the written text in spoken Arabic rather than the standard one. For example, reading the word "شاحن" which means "charger" as "مريض" which means "sick" possibly because of the visual error that led to the word "ساخن" which means "sick" in Palestinian dialect followed by a semantic error which led to the final word "مريض".
- **Morphology**: Arabic has a rich morphological structure in both nouns and verbs. Both nouns and verbs can be constructed from three-consonant roots and either nominal (for nouns) or verbal templates (for verbs). This leads to the identification of the morphological error types in deep dyslexia; whether the root is the same and the template has changed or vice versa.

Different error types that characterise deep dyslexia (Friedmann and Haddad-Hanna, 2014):

- **Semantic error**: such as reading the word "طبل" which means "drum" as "دف" which means a "hand drum".
- **Morphological error**: such as reading the word "تفاحة" which means "an apple" as "تفاح" which means "apples".
- **Visual error**: such as reading the word "رحمة" which means "mercy" as "حمامة" which means "dove".
- **Visual-then-semantic error**: such as reading the word "تراب" which means "soil" as "عصفور" which means "bird". This might be due to the visual error "غراب" which means "crow" and then a semantic error which is "bird".

Individuals with deep dyslexia read by the semantic route and therefore, they have severe difficulty in reading words that do not have precise semantic content, such as reading function words and abstract words, as explained below:

- **Function word error**: such as reading the word "إلى" which means "to" as "من" which means "from".
- **Abstract word error**: such as reading the word "شمعة" which means "candle" as "شمس" which means "sun".

Since morphological errors are one of the error types that characterise deep dyslexia, therefore, reading morphologically complex words (verbs and nouns) is difficult, as discussed below:

- ***In terms of morphologically complex verbs***: Such verbs either cannot be read or can be read with several errors, such as morphological, morphological and visual, visual, visual-then-semantic and visual, semantic or morphological errors. An example of the morphological-then-semantic errors is reading the word "يجيبانه" which means "they both are answering him" as "سيارة" which means "car". This might be due to the morphological decomposition of the word that extracted its root which is "جيب" and means "Jeep" and then a semantic error that leads to the final word "car".
- ***In terms of morphologically complex nouns***: Reading such nouns can produce similar errors to the previously discussed verbs; morphological errors (such as reading "جذور" which means "roots" as "جذر" which means "root") and semantic errors (such as reading "سيارات" which means "cars" as "ساق" which means "drove".)

Further, individuals with deep dyslexia either cannot read non-words or produce errors to read them as a known word such as reading the non-word "كندرة" as "كبيرة" which means "big" due to a visual error.

Finally, seven developmental Arabic dyslexia types have been identified and explained by (Friedmann and Haddad-Hanna, 2014). However, when comparing them with the ones explained in Section 2.2.4, three missing types have not been identified in Arabic dyslexia (one belongs to peripheral dyslexias while the other two belong to central ones). These are (1) letter identity dyslexia, (2) phonological dyslexia and (3) access to semantics dyslexia. This might be due to the lack of either diagnoses lists that diagnose these types in Arabic or participants who do not have these dyslexia types or it might be due to its absence in this language.

In ***letter identity dyslexia***, individuals with such dyslexia are unable to name a letter, identify both the letter's name and its sound and match the upper and lower cases of the same letter. These problems occur due to a deficit in the orthographic-visual analyser, precisely the function that is responsible for identifying abstract letters and not due to a visual deficit (Friedmann and Coltheart, 2016). The question is; *can individuals with Arabic dyslexia have this type?* The answer is probably yes. An individual with Arabic dyslexia can have a deficit in this function that results in similar problems except for the different cases of a letter. There are no upper and lower cases for letters in Arabic, instead, there are different forms for each letter based on its position within a word which might cause an individual with Arabic dyslexia to fail in matching these forms.

In ***phonological dyslexia***, individuals with such dyslexia are unable to read non-words and morphologically complex words (usually long words). These problems were due to a deficit in different parts of the sub-lexical route leaving the lexical route to proceed with the reading by itself. Therefore, words that have been stored in the orthographic input lexicon and phonological output lexicon are read correctly while non-words are not. In addition, three phonological dyslexia types have been addressed in phonological dyslexia and explained by (Friedmann and Coltheart, 2016). Now, the question is; *can individuals with Arabic dyslexia have any of these phonological dyslexia types?* The answer is probably yes, as explained below:

- Letter-to-phoneme conversion phonological dyslexia faces problems in converting each letter to its single phoneme, which is also applicable in Arabic where each letter has its own single phoneme.

- Multi-letter phonological dyslexia faces problems in converting a group of letters to their single phoneme, which can also be found in Arabic. For instance, converting the letters "وا" (that indicates the plural past tense of a masculine verb) in the word "يعملوا" into its phoneme

"u". Unfortunately, these letters can be pronounced mistakenly by an individual with dyslexia as two single letters "wa".

- Phonological-output-buffer-phonological-dyslexia faces problems in reading complex long words, which also exists in Arabic due to the Arabic morphological rules that produce Arabic words.

Finally, individuals with ***access to semantics dyslexia*** are able to read aloud correctly but unable to understand written words. This problem results from a deficit in either accessing the semantic lexicon from the orthographic input lexicon or the conceptual or semantic system itself (Friedmann and Coltheart, 2016). Now, the question is; *can individuals with Arabic dyslexia have this type?* The answer is probably yes, because it does not relate to a certain language; in fact, it is a general deficit that affects reading comprehension.

To end, the discussions of the previous types and their relatedness to Arabic are just arguments that are based on theory, so empirical studies are needed to prove or disprove them.

2.3.4.3 Frequency of Arabic Dyslexia Types

As discussed earlier, the reading difficulties and the reading error rates are sensitive to language. Therefore, some dyslexia types are common and frequent in specific languages but uncommon in others. As this research targets Arabic, the frequency of each Arabic dyslexia type is illustrated in Table 2.2 according to (Friedmann and Haddad-Hanna, 2014).

Table 2.2: Frequency of Arabic Dyslexia Types in (Friedmann and Haddad-Hanna, 2014)

Arabic Dyslexia Type	Frequency(%)
Letter Position Dyslexia	**51%**
Atentional Dyslexia	3%
Letter Identity Dyslexia	NA
Visual Dyslexia	8%
Neglect Dyslexia	1%
Surface Dyslexia	12%
Phonological Dyslexia	NA
Vowel Letter Dyslexia	**18%**
Deep Dyslexia	7%
Access to Semantics Dyslexia	NA

2.3.5 Summary

Arabic is one of the most used languages in the world. It is spoken by millions of individuals as their first or second language. Since dyslexia is affected by the language and therefore by Arabic, so this research focuses on Arabic dyslexia especially due to the lack of research in this area.

Arabic has many features that contribute to the manifestation of dyslexia. For instance, the cursive nature of Arabic, the use of dots to discriminate between letters and the different shapes a letter

can have based on its position within the word (Elbeheri, 2005).

Developmental dyslexia can be classified into different types in Arabic, based on the impaired component of the dual-route model for single-word reading as discussed in Section 2.3.4. The differences between these types are due to the part of the model which is impaired and the features of the Arabic orthography (Friedmann and Haddad-Hanna, 2014). The majority of Arabic dyslexia types affect reading only at the word level such as letter position dyslexia and vowel letter dyslexia. Letter position dyslexia and vowel letter dyslexia are considered by (Friedmann and Haddad-Hanna, 2014) as the most frequent Arabic dyslexia types that are encountered among individuals with Arabic dyslexia. However, each Arabic dyslexia type has special difficulties that should be considered. Therefore, this research aims to consider such difficulties in order to provide suitable support by combining the theoretical framework of dyslexia, discussed in the previous sections, with current practices towards it. So, the current interventions toward dyslexia must be explored in order to discover their gaps and weaknesses and then overcome them in this research. This is what the next section will discuss.

2.4 Interventions

Individuals with dyslexia, as mentioned earlier, face different difficulties. However, there are no medication treatments that can be used to cure them. But, it is important to provide early interventions and treatments to reduce the long term problems that they face and promote future success in both school and the workplace. These early interventions can help in increasing confidence that may prevent anxiety and depression towards this difficulty (Walker, 2014).

Different interventions may overcome different dyslexia problems. These interventions can be categorised into technological and non-technological interventions as illustrated in Figure 2.8. Each has been detailed in the sub-sections below.

2.4.1 Non-Technological Interventions

Non-technological interventions refer to the interventions that do not use technology, such as teacher intervention, parent intervention, school intervention, etc. They can be divided into human interventions and non-human interventions. Each one is explored below.

2.4.1.1 Human Interventions

Human interventions refer to the interventions used by people to help individuals with dyslexia. Teachers are examples of such people. As there are no two learners with dyslexia with exactly the same symptoms, teachers can use an individualised approach for each learner with dyslexia to (1) identify their problem, (2) work at their speed, (3) teach them what they need (Béland and Mimouni, 2001; Sampath et al., 2010) and (4) provide the teaching strategies and techniques that

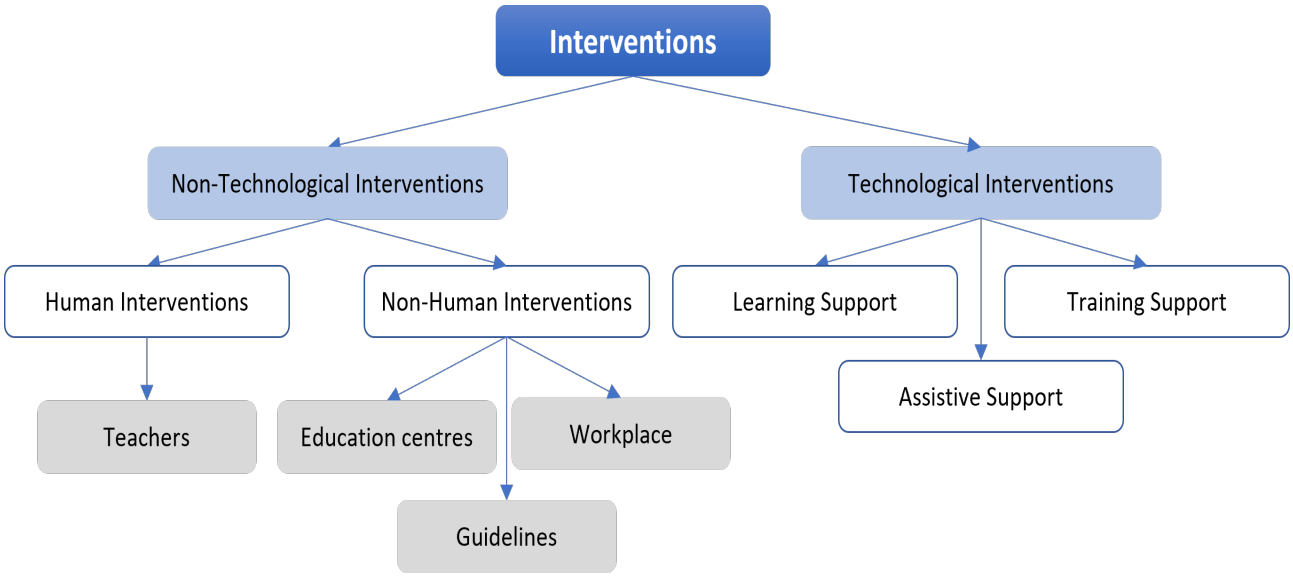


Figure 2.8: Classification of Different Interventions for Dyslexia

suit their needs (Sampath et al., 2010).

Teachers may also use the preferred learning styles of learners with dyslexia to improve their learning. (Exley, 2003) has investigated the impact of teaching students with dyslexia based on their preferred learning style on their learning. The visuospatial/kinesthetic learning style was the preferred style by the majority of these students. It improved their learning and understanding in both math and spelling. However, the number of participants was small and more investigation is required.

2.4.1.2 Non-human Interventions

Non-human interventions refer to the interventions used by organisations to help individuals with dyslexia such as education centres and workplaces and the guidelines to be followed to treat such individuals.

In terms of ***education centres***, schools, for instance, have systems that provide several accommodations for children with dyslexia such as no spelling penalisations, reading aloud assessment questions to them and giving them extra time on reading tasks and major assessments (Walker, 2014).

Other education centres aim to improve the phonological awareness of children with dyslexia. (Aboras et al., 2012) have designed and evaluated an Arabic remediation program using materials appropriate for male and female Arabic speaking children with dyslexia in the age range 6½ to 10½ years old. The program contained different activities covering both analytic and synthetic phonological skills to provide a better effect on the reading skills. These activities included sound blending, sound segmenting, reading and spelling. The children were evaluated twice via the Arabic dyslexia assessment test. The first evaluation was applied directly after attending the training

sessions while the other one was applied one year after attending these sessions. The evaluation considered both the improvement and the stability in the children's condition. The first evaluation revealed a significant difference between the scores before and after attending the training sessions in all test items. Younger children scored higher than older ones. The second evaluation revealed the same results.

On the other hand, the ***workplaces*** adapted themselves in a more convenient way to help their employees with dyslexia. For instance, giving such employees more time to finish specific tasks, providing them with assistive technology such as a digital recorder and giving them verbal instructions instead of written ones (Béland and Mimouni, 2001; Sampath et al., 2010).

In terms of ***guidelines***, there are various guidelines which, if followed, can help to minimise dyslexia difficulties, as listed below:

- *Reading difficulties*: different methods can be used to decrease dyslexia reading difficulties based on developmental dyslexia types detailed earlier (Friedmann and Coltheart, 2016).

    1. Letter position dyslexia: Since this type tends to migrate letters within the target word, then using the finger to trace the words letter-by-letter and avoiding using different colours for each letter will tend to decrease the rate of migration errors.
    2. Attentional Dyslexia: Since this type tends to migrate letters between adjacent words, then covering the neighbouring words will prevent letters from migrating between them and thus decrease the rate of migration errors. This can be applied by using cardboard with a word-sized hole in its centre.
    3. Neglect Dyslexia: Since this type tends to neglect the left side of the target word, then attracting the attention to the left side of the word will tend to decrease the rate of neglect errors by:
        (a) Using the left-hand index finger to trace the word, letter-by-letter.
        (b) Using the left finger to the left of the target word.
        (c) Placing a small blinking light or a coloured vertical line to the left of the target word.
        (d) Presenting the target word vertically.
        (e) Doubling spaces between the letters in the target word.
    4. Surface Dyslexia: this type, as mentioned earlier, comprises other sub-types that can be treated as follows:

(a) Inter-lexical surface dyslexia: Since this sub-type affects reading aloud, then individuals with this sub-type should not be forced to read aloud.

(b) A deficit in the orthographic input lexicon: Since this sub-type affects both the lexical decision of pseudohomophones and the understanding of homophones and potentiophones, then individuals with this sub-type can be treated by repeatedly displaying words, reading intensively and connecting between the written word with its phonemes. Another treatment that can be used is strengthening the multi-letter, grapheme-to-phoneme conversion, and morphological orthographic rules.

5. Phonological Dyslexia: this type, as mentioned earlier, comprises other sub-types that can be treated as follows:

   (a) Letter to phoneme conversion phonological dyslexia: Since this sub-type faces problems in converting single letters into their phoneme, then teaching them explicitly the rules of letter-to-phoneme conversion might be helpful.

   (b) Multi-letter phonological dyslexia: Since this sub-type faces problems in converting multiple letters into their phoneme, then explicitly teaching them the rules of multi-letter conversion might be beneficial.

   (c) Phonological output buffer dyslexia: Since this sub-type faces problems in reading long words and non-words, then breaking the target word into smaller units, such as units of consonant-vowel or syllables during reading might decrease the problem and lead to reading such words correctly.

- *Writing and spelling difficulties*: Several strategies can be used to help learners with dyslexia to write and spell words correctly. For example (Béland and Mimouni, 2001; Sampath et al., 2010):

  1. Using rhyme words such as drink, think, stink, etc.
  2. Using syllables to help in spelling long words.
  3. Using funny pictures to link them to their sounds and facilitate splitting the syllables.
  4. Using pictures to link them to words and ease learning.
  5. Using the phonics-learning technique in creating words by combining letters and then creating sentences by using these words.

2.4.2 Technological Interventions

Technological interventions refer to the interventions that use technology to support individuals with dyslexia by providing learning, training and assistance. These interventions can be categorised

based on the type of support as shown in Figure 2.8. Each category is explored below.

2.4.2.1 Learning Support

Different techniques have been used to support the learning of individuals with dyslexia. A study has described a number of user involvement issues during the development of standalone interactive learning systems for Arabic dyslexia and dyscalculia (Al-Abdulkarim et al., 2010). They found that involving special learning difficulty specialists during the design process was essential. They helped in transferring the domain knowledge efficiently. Moreover, exploratory design approaches faced challenges in language, culture and context. Therefore, they should be taken into consideration.

Another proposal was suggested by (Alsobhi et al., 2015a) who proposed a Dyslexia Adaptive E-learning framework that adapts itself according to individuals' dyslexia types to improve the educational process taking into consideration four dimensions: presentation, hypermediality, acceptability and accessibility and user experience. In the ***presentation*** dimension, the information should be presented and organised in small paragraphs to decrease the cognitive load of learners with dyslexia. In terms of the ***hypermediality*** dimension, the information should be presented using media that tackles all forms of senses, including touch, to accommodate the differences between learners with dyslexia and thus improving the learning process. In terms of the ***acceptability and accessibility*** dimension, both attributes and needs of the users should be considered. Finally, in terms of the ***user experience*** dimension, the quality of the system's design along with its interaction with the learner should be considered. For instance, consider the learners' needs and the activities they want to perform before developing the e-learning system.

On the other hand, (Gooch et al., 2016) preferred the gamification technique. They have investigated the effect of a gamification platform known as ***ClassDojo*** on learners with dyslexia in primary school. They offered these contributions: establishing a number of practices based on the pedagogical use of gamification and analysing the design of the gamification platform from the teacher practices' perspective which revealed the importance of encouraging students in customising their badges, where badges represent achievement rewards.

Another group of researchers developed their learning systems in the context of games instead of only adding gamification elements as in (Gooch et al., 2016). For instance, (Vasalou et al., 2017) have designed digital game-based learning (***Words Matter***) for children with dyslexia. Qualitative data was collected from children's verbal and non-verbal interactions along with their game logs. (Vasalou et al., 2017) have found that the children were spontaneously engaged regarding content, performance, experiences and actions. Further, a variety of new opportunities for learning were catered for by tutor and student-initiated interventions.

Another attempt was by (Al-Wabil et al., 2010) who described the design phase of a multimedia

educational game known as ***Memory Challenge***. The game was intended for children with Special Learning Difficulty especially dyslexia and attentional deficit disorder who have problems in their short-term memory, by teaching them the learning strategies for memory to improve their cognitive skills. Children with Special Learning Difficulty, domain specialists and practitioners have been involved in the different stages of the design phase. Unfortunately, the game has not been fully developed and tested with the target children, therefore it has not been evaluated.

Finally, (El Kah and Lakhouaja, 2018) proposed a set of Arabic games to strengthen the reading and spelling skills by combining therapeutic goals (training and assisting) and the basic aspects of electronic games (entertainment and joy). The games targeted Arabic children (from five to eight years old) with either dyslexia or dysgraphia. The games considered problems in short-term memory, disturbed visual memory, poor phonological awareness (sound-letter association and sound discrimination), difficulty in word building, and lack of vocabulary. The games proved their efficiency in terms of validity and reliability and their distinctive role in enhancing the learning process for both children with and without dyslexia.

2.4.2.2 Training Support

Different proposals have been published in the literature to train individuals with dyslexia in reading and spelling. It is important to differentiate between the training intervention and the learning one described above. Training is about practicing already known knowledge by learners while learning is about teaching them new unknown knowledge.

(Martins et al., 2016) have developed a mobile application to train individuals with dyslexia in reading the Portuguese language. A list of pre-defined words was embedded in the system. These words appear randomly to the user one at a time. Each time the individual should read the word aloud and the system, by using a speech recognition tool, checks the validity of the reading. A maximum of five attempts were given to the individual to read each word correctly. If the reading was incorrect, then the application will display a suggested word that reflects the incorrect reading. The application was evaluated using four different tests. Unfortunately, none of these tests checked the reading improvement of individuals with dyslexia after using the proposed system.

On the other hand, (Lyytinen et al., 2007) have developed a mobile game-based application known as ***Literate*** to enhance the accuracy of perceiving and memorising phonemic sounds in the Finnish language and (2) learn to fluently connect them to their equivalent orthographic stimuli. The game was intended for children with dyslexia between five and eight years old. They first listen to a spoken letter and then choose its written counterpart from a list of choices that appears as falling balls to increase their enjoyment. The exercises' difficulty increases by introducing the spoken phonemes followed by syllables and words. Similarly to other games, the experience of success was the most

natural reward. The results revealed that the ***Literate*** game improved participants' blending performance and such participants performed better than the others who were only supported by the school. Additionally, children can be helped in reaching their level of reading by applying intensive practice mixed with enjoyment in order to increase their fluency and thus comprehension. Also, (Rello et al., 2014) have developed a mobile game-based application Known as ***DysEggxia*** to train and improve the Spanish spelling skills of children with dyslexia. The exercises present misspelt words to be solved. These words were created based on the linguistic knowledge extracted from the errors found in the written texts of individuals with dyslexia. The proposed game was evaluated in terms of the improvement in reading and writing skills. After four-weeks of playing the game, the individuals with dyslexia made fewer writing errors but without a significant effect in improving reading errors. They concluded that error-based exercises improved the spelling skills of individuals with dyslexia more than correct word-based exercises.

A final intervention to discuss is the framework developed for evaluating Arabic training tools for dyslexia (AlRowais et al., 2013, 2014). The framework has integrated both the Arabic features and its related cultural context to guide the designers of Arabic dyslexia training tools through a set of guidelines supporting the evaluation of such tools. Thus, helping Arabic students with dyslexia to obtain literacy skills and achieve their potential. The framework was evaluated by experts through interviews and questionnaires. The findings suggested approving the majority of the framework's elements but excluding some of them. Further, some elements were improved and new ones were added. However, the effectiveness of the framework has not been evaluated.

2.4.2.3 Assistive Support

A variety of approaches have been used to assist individuals with dyslexia with their reading. Developing a reader was one of these approaches used by (Lukeš, 2015). This reader supports features such as text highlighting, linguistic guidance, text-to-speech control and text formatting presets. It targeted 9 to 11 years old English students who need assistance with literacy. The results revealed the simplicity of the reader's design and its ability to encourage students who have a negative attitude towards reading to access text regularly.

However, when we look carefully at the reader's design, we find very small icons and low contrast between the foreground and background colours. Therefore, the icons are difficult to read. Also, the results were presented using terms such as "several" and "many" without mentioning the exact number or percentage of the participants, which makes it hard to understand the benefits of this reader.

(Kanvinde et al., 2012) also used the reader approach by developing an eBook reader for Android users. This reader displays eBooks in a more accessible format, that suits individuals with dyslexia.

It supported several features that already exist in other readers such as text-to-speech technology (Lukeš, 2015) while others were new, such as displaying the text layout based on the reader's preferences. The reader targeted Spanish individuals with dyslexia where their reading was tested whilst using the reader to measure the readability of the text layout. Several parameters were considered such as font, size, character and line and paragraph spacing.

(Rello et al., 2013) have also developed an eBook reader but for iOS users known as ***DysWebxia***. This reader's settings can be customised based on the preferences of individuals with dyslexia. It supports several features such as font size and type, colour and displaying synonyms for complex words. Unfortunately, the effectiveness of both readers (Kanvinde et al., 2012; Rello et al., 2013) has not been tested.

Proposing a customised toolbar known as ***Firefixia*** was another approach used by (de Santana et al., 2013) to assist individuals with dyslexia with their reading. This toolbar targeted adult web users with dyslexia to enable them to customise the presentation of their web content based on their preferences. A variety of features were offered by that toolbar such as specifying text size, text alignment, background colour and line spacing. The results revealed that the most useful characteristics, based on the participants' opinions, were text alignment, colour and size. However, the number of participants was small and the evaluation method was unreliable.

Developing an add-on module was a third approach used by (Gregor and Newell, 2000) to assist individuals with dyslexia with their reading. The module was for Microsoft Word. It provided a highly configurable word processing environment to minimise the reading problems of individuals with dyslexia during reading or writing a document. The proposed system provided individuals with dyslexia with two distinct programs: a Preference program and a Reading/Editing program. The Preference program enables the individual to change a number of display parameters to deal with their visual problems such as changing colour settings (background and foreground), spacing (character, line, and paragraph), and colouring reversible characters. The result of this customisation is used by the Reading/Editing program for all the word-processing of the individual and offers more valuable options. For instance, The Speak text option reads all or part of the document to the individual. This may help individuals with dyslexia to identify misspelt words and learn the correct pronunciation of multi-syllabic ones. The results revealed that this module was simple, preferred by the participants and provided them with an easily configurable environment that assisted them in reading documents. However, the number of participants in the evaluation was also small and thus the results cannot be guaranteed.

Similar to (Gregor and Newell, 2000), a prototype developed by (Gregor et al., 2003) (known as ***SeeWord***) focused on investigating whether the visual changes to the word processing environment

in which individuals with dyslexia work, would improve their reading and writing of text. The results revealed that using the preferred settings reduced the number of reading errors. Again, the number of participants was small and thus the results cannot be guaranteed.

Following a set of guidelines that promote the accessibility of electronic content for dyslexia is another approach that can be used to assist individuals with dyslexia. (Al-Wabil et al., 2006) was one of the works that adapted these guidelines to suit the Arabic text due to its specific nature. An example of these guidelines:

- Using a font size of 16-20 points.
- Using right alignment for the text because of the Arabic nature.
- Using Arabic Transparent or Simplified Arabic Fixed font.
- Using bold to emphasise text or a combination of bold and colour.
- Using diacritics in the Arabic text for reading accuracy and comprehension.

A different study has proposed usability features to improve Arabic assistive technologies for dyslexia such as (Aldabaybah 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 dyslexics' assessment of the usability and enhanced their academic achievement level. Finally, there are other ways that may benefit from technology and help individuals with dyslexia, such as (Béland and Mimouni, 2001; Sampath et al., 2010):

- Using speech recognition software to convert the speech of an individual with dyslexia into written text due to the excellent verbal skills that some of them may have.
- Using electronic organisers to facilitate such individuals in their writing and organising daily activities.
- Using word processors to auto-correct spelling mistakes.
- Using "text-to-speech" tool in web browsers to read the text on the computer's screen. This may help individuals with dyslexia to overcome their poor reading.

2.4.3 Summary

As dyslexia is a lifelong reading difficulty, there were various interventions provided to individuals with dyslexia to help compensate for or minimise their difficulty. Some of these interventions were human, such as teachers, who, for instance, teach individuals with dyslexia using their preferred

learning style (Exley, 2003). Other interventions were non-human such as regulations and policies offered by workplaces to their employees with dyslexia to help them complete their tasks in a convenient way (Béland and Mimouni, 2001; Sampath et al., 2010). On the other hand, other interventions used technology to offer learning, training or assistance to individuals with dyslexia. For instance, using mobile games to learn a certain language (Martins et al., 2016) or using e-book readers to display the text layout based on the reader's preferences (Lukeš, 2015).

2.5 Conclusion

Reading opens the way to learn other concepts. Unfortunately, if reading is impaired, as in dyslexia, then the individual's life will be negatively affected. It is widely believed that dyslexia is neurological in its origin and runs in families regardless of ethnicity. However, there is still no formal definition for dyslexia. It is well known that the phonological awareness of individuals with dyslexia is affected, resulting in other academic problems such as problems in writing, spelling and mathematics and behavioural problems such as low levels of self-esteem.

Since dyslexia is a lifelong difficulty, then it should be understood in order to offer them suitable support and overcome their difficulty and thus succeed in school and work. To better understand dyslexia, different attempts exist in the literature to classify them into different types. One attempt classified dyslexia based on the impaired component of the dual-route model for single-word reading. This classification is adopted by this research because the model is straightforward and reliable. Each type has its own symptoms which, if understood, then appropriate support can be provided. Dyslexia is also affected by language which, in turn, affects the manifestation of dyslexia. Because this research is targeting Arabic, then Arabic orthography is considered. For instance, the cursive nature of Arabic and using dots to discriminate between letters.

Different interventions are available for individuals with dyslexia to help them cope with their difficulties. These interventions can be classified into non-technological and technological interventions. The non-technological interventions refer to interventions that do not use technology such as the policies and regulations used by workplaces to help their employees to complete their tasks in a convenient way. In contrast, technological interventions refer to the interventions that use different technologies to offer learning, training or assistance support. For instance, using games to improve short-term memory, visual memory and phonological awareness.

In this chapter, we have reviewed both (1) the theoretical framework of dyslexia to better understand it by exploring its definition, causes and different types and (2) the existing interventions for dyslexia to identify their limitations to overcome them in this research. Thus, this research is building on theory and practice, to provide suitable support for individuals with dyslexia.

Based on theory, it was obvious that individuals with dyslexia are different especially in their difficulties, and according to practice, these individuals should be supported by what is called "Adaptation". Adaptation is one of the powerful techniques that can be used to provide each individual with dyslexia with the appropriate support for their needs. A detailed discussion about adaptation and its related work is provided in the next chapter.

Chapter 3

Adapting E-learning Systems

3.1 Introduction

The previous chapter explored dyslexia in terms of its definition, causes, symptoms and types. Since this work focuses on Arabic, therefore Arabic dyslexia was also highlighted. To help individuals with dyslexia overcome their difficulties, different interventions were proposed in different domains such as workplaces and e-learning. With regard to e-learning, the majority of these interventions treated individuals with dyslexia as a single class even though most research pointed out that they differ in, for instance, reading difficulties and therefore the dyslexia type they have. So, it is important to tailor these e-learning systems to their needs and interests by using the "Adaptation" technique. Hence, this chapter presents the concept of e-learning, adaptation in e-learning along with some examples of adaptive e-learning systems.

3.2 E-learning Systems

E-learning technology has gained interest due to the popularity of the Internet. E-learning is any type of learning that is delivered through online communication resulting in a very broad e-learning scope (Nagy, 2005). So, e-learning is defined as (Holmes and Gardner, 2006, p. 14):

"Online access to learning resources, anywhere and anytime".

E-learning provides learning to any person such as students, trainees and lifelong learners. Unlike traditional learning, e-learning usually conducts asynchronous learning by offering flexibility in both location and time for learning. This includes learners who are least mobile (such as children in hospitals) and most mobile (such as aeroplane pilots) (Holmes and Gardner, 2006, p. 30-31)(Vassileva, 2012). On the other hand, e-learning systems are usually based on a "one-size-fits-all" approach that delivers the same content to learners using the same teaching method regardless of their individual differences. Precisely, the diversity of learners, their abilities and knowledge and learning context are neglected by these e-learning systems (Maravanyika et al., 2017; Alshammari et al.,

2014). This may result in presenting the learning content at either too low or too high a cognitive level. Consequently, learners may become bored or frustrated (Maravanyika et al., 2017) and therefore the efficiency of the learning process is negatively affected. To overcome this problem, adaptive e-learning systems are used (Vassileva, 2012). Adapting e-learning systems enables considering the different needs of learners by personalising and recommending the learning material to suit their needs (Alshammari et al., 2014). Details are provided below.

3.3 Adapting E-learning

3.3.1 Adaptation

Adaptation means tailoring the system's interaction to individual user's needs. For instance, changing the starting point in an e-learning system for each learner based on their current knowledge level (Brusilovsky, 2012; Maravanyika et al., 2017).

Regarding adaptation, two terms are often used interchangeably; ***adaptive*** and ***adaptable***. An ***adaptive*** system is one that is able to adapt automatically to the users based on its assumptions about the user needs. On the other hand, an ***adaptable*** system is one that allows the user to change its parameters and then adapts its behaviour accordingly (Surjono, 2014). In short, an adaptive system adapts its behaviour automatically whereas the behaviour of the adaptable system is personalised by the user (Klašnja-Milićević et al., 2017).

Adaptation can be used to minimise the problems the user encounters without adaptation or to enhance the user's experience. In other words, the adaptation aims to enhance the system usability and user satisfaction (De Bra, 2008).

Now, the question is: how can a system adapt?

To accomplish adaptation, three essential stages should be followed (see Figure 3.1):

- Collect data about the user, whether offline or dynamically, to build the user model.
- Provide adaptation by employing the user model to build the adaptive system.
- Keep track of any changes in the user model to update the adaptation model accordingly.

To develop an effective adaptive system, it must be properly planned. To do so, the six questions, illustrated in Figure 3.2, must be considered and answered carefully (Knutov et al., 2009; Ghaban, 2020; Alshammari, 2016):

- Where can we apply adaptation? (Where?)
- Why do we need adaptation? (Why?)
- What can we adapt? (What?)

- How can we adapt? (How?)
- What can we adapt to? (To What?)
- When can we apply adaptation? (When?)

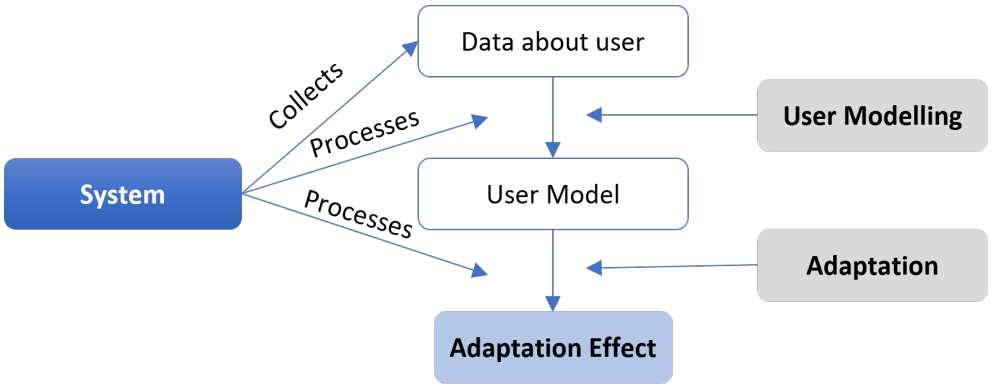


Figure 3.1: Adaptation Stages (Brusilovsky, 1996)

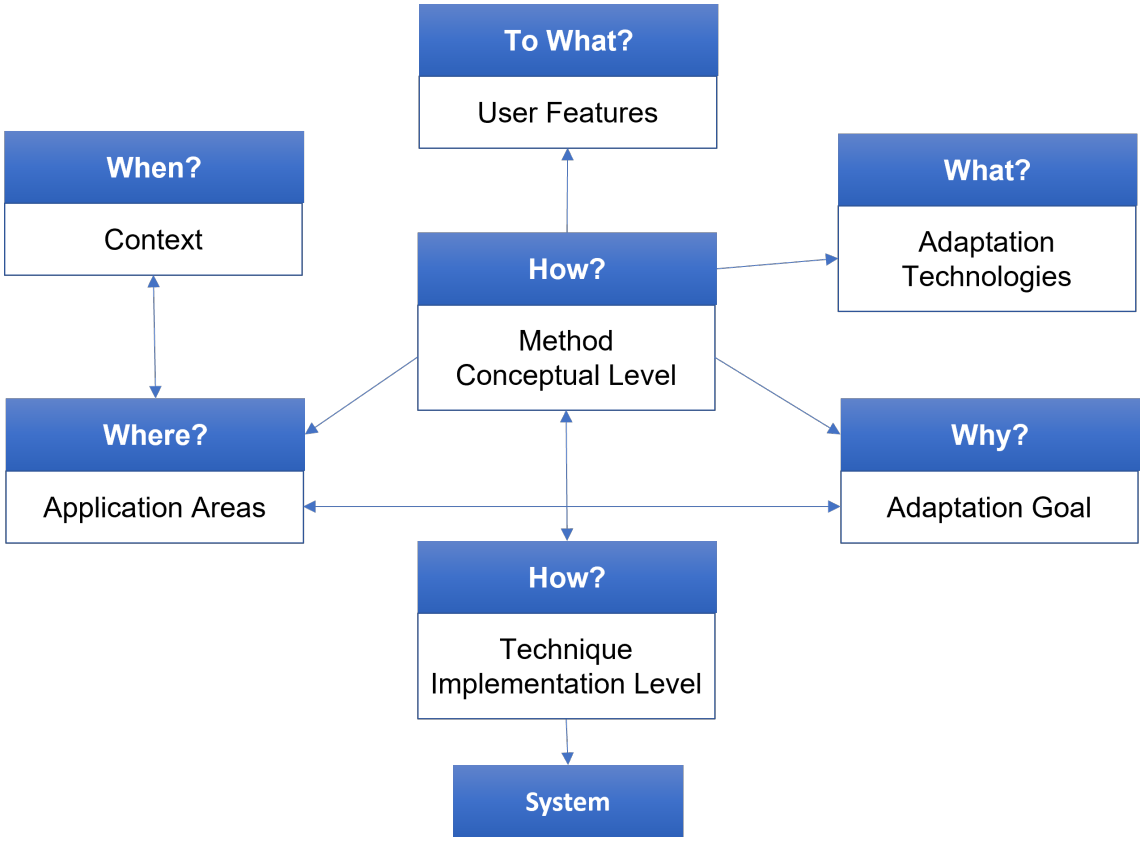


Figure 3.2: Classification of Adaptive Hypermedia System's Methods and Techniques (Knutov et al., 2009)

The ***"Where can we apply adaptation?"*** question refers to the domain application area to which the adaptation can be applied. Any system with a huge amount of information and/or different features and interfaces can be adapted such as educational systems, on-line information systems, on-line help systems, adaptive search engines and shopping sites (De Bra and Ruiter, 2001; Brusilovsky, 1998; Alshammari, 2016; Ghaban, 2020). An example of a shopping site is

Amazon that recommends a customer different products based upon their previous behaviour and the system's goals.

The ***"Why do we need adaptation?"*** question refers to the main goal and importance of designing such an adaptive system. For instance, some e-learning systems apply adaptation to increase learner outcomes while others aim to enhance usability and satisfaction (Ghaban, 2020; Alshammari, 2016; Motti and Vanderdonckt, 2013).

The ***"What can we adapt?"*** question refers to the part of the system that will appear differently for different users, in short, the part that will be adapted. For instance, adapting the content of the system (Brusilovsky, 1998).

The ***"How can we adapt?"*** question refers to the methods and techniques that will be used in the adaptation process. For instance, using the conditional text technique to adapt the system's content by hiding from the learner, some pieces of information that are irrelevant to their knowledge or goals (Brusilovsky, 1998; Ghaban, 2020; Alshammari, 2016; Motti and Vanderdonckt, 2013).

The ***"What can we adapt to?"*** question refers to the attributes that can be considered as a source of adaptation. Some of these attributes are related to the learner while others are related to the environment. Learner attributes can be stable attributes such as the learner's background, knowledge, learning style and personality or volatile attributes such as emotion, interests and goals. Environmental attributes may include the physical environment itself, devices used or context (Brusilovsky, 1998; Ghaban, 2020; Nguyen and Do, 2008; Garzotto and Cristea, 2004).

The ***"When can we apply adaptation?"*** question identifies the time at which the adaptation process will be performed. It could be performed at run time, design time or compilation time (Motti and Vanderdonckt, 2013; Ghaban, 2020).

As the learning context is the focus, the adaptive e-learning systems are discussed below.

3.3.2 Adaptive E-learning Systems

Over the last few decades, ***adaptation in e-learning*** has gained a huge interest among researchers in computer education (Klašnja-Milićević et al., 2017). Adapting e-learning systems considers the individual differences of learners and their learning situation which in turn can enhance the learner's progress, outcome and the quality of the learning environment and can enable learners to learn with less effort leading to a higher level of satisfaction. Adaptive e-learning systems provide a personal learning experience to the learner by adapting the learning material to, for example, learner characteristics. These characteristics can be the learner's prior knowledge, cognitive traits, preferred learning style, affective states, interest, goal, etc. (Graf et al., 2012; Kamceva and Mitrevski, 2012). This personal learning experience is usually accomplished by using an explicit learner model that keeps the learner's information such as knowledge, preferences, goals and any other feature that

can be used as a source for the adaptation process (Brusilovsky, 2012).

Further, adaptive e-learning systems attempt to protect the learner from cognitive overload and from getting lost in the hyperspace of large-scale learning materials (Surjono, 2011). Therefore, adaptive e-learning systems aim to (1) deliver the right content to the right learner at the right time using the most appropriate way (Shute and Towle, 2003; Esichaikul et al., 2011) and (2) enhance the usability of the learning material which in turn improves the efficiency of the adaptive e-learning systems and therefore improves the learning and results in better learning outcomes (Esichaikul et al., 2011).

Each adaptive e-learning system contains mainly, three models: learner model, domain model and adaptation model (Esichaikul et al., 2011; Surjono, 2014; Triantafillou et al., 2003) as shown in Figure 3.3. Each model is detailed in the following sub-sections.

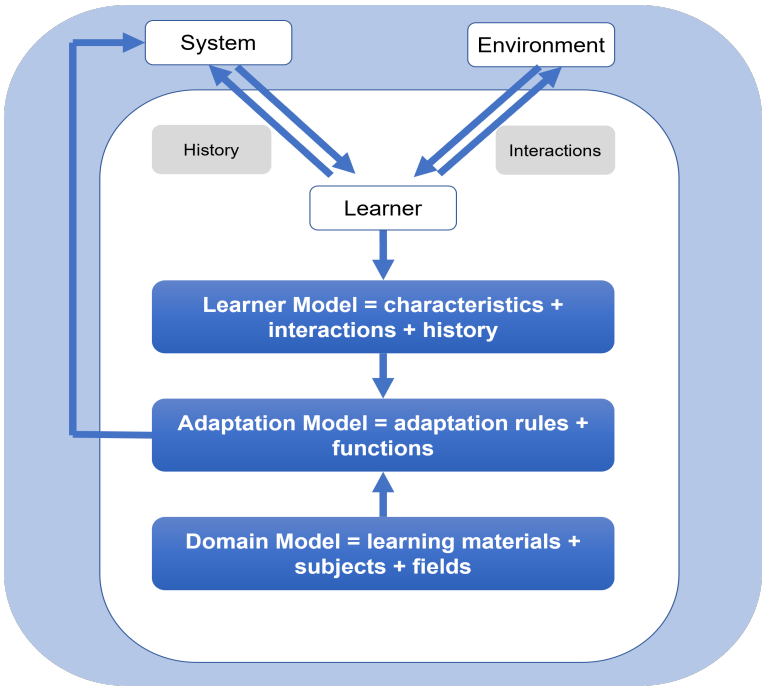


Figure 3.3: Adaptive E-learning System's Components (Ennouamani and Mahani, 2017)

3.3.2.1 Learner Model

The learner model is the main component of the adaptive e-learning system that represents the learner characteristics in a structured way (Ennouamani and Mahani, 2017). An effective learner model accurately diagnoses the learner and predicts their needs to adapt the learning material and process accordingly (Chrysafiadi and Virvou, 2013). The learner model involves three main stages (Ghaban, 2020):

- ***Learner model information:*** which refers to what is being modelled.
- ***Learner model representation:*** which refers to the way of representing the learner's characteristics.

- ***Learner model elicitation:*** which refers to the way of obtaining these characteristics.

Learner Model Information

This stage determines the learner features that can be used in the adaptation process (Ghaban, 2020). Some of these features are static while others are dynamic. The static features are set before starting the learning process by collecting them from the learner and remain stable throughout the learning process. On the other hand, the dynamic features change frequently and are collected during the system-learner interaction process (Chrysafiadi and Virvou, 2013). In addition, the learner features can be domain-specific or domain-independent (Esichaikul et al., 2011; Chrysafiadi and Virvou, 2013; Nguyen and Do, 2008).

Domain-Specific Features

These features represent the learner knowledge level and their understanding of the curriculum (Esichaikul et al., 2011).

Knowledge

The learner's knowledge is the most important feature to be modeled which represents the learner's knowledge level about a certain subject or domain. Learner's knowledge might change over time by either increasing the learner's understanding or through their forgetting. Therefore, the system should be able to track these changes and reflect them to the learner model accordingly (Brusilovsky and Millán, 2007).

Domain-Independent Features

The domain-independent features represent information about the learner's skills which are collected from their behaviour (Esichaikul et al., 2011). These features may include the learner's motivational states, background and interest (Nguyen and Do, 2008; Esichaikul et al., 2011).

Background

The learner's background is the learner's knowledge beyond the adaptive system's domain (Brusilovsky and Millán, 2007). It covers knowledge that the learner gained in the past (Nguyen and Do, 2008) and not part of the learner's current domain (Ghaban, 2020). It includes different features such as language ability (native or non-native speaker) and profession (student, assistant, teacher). It is mostly used for content adaptation. However, the learner's background differs from the learner's knowledge by not going into details as in the learner's knowledge (Brusilovsky and Millán, 2007).

Interests

Learner interest is one of the essential parts of user modelling for adaptive information retrieval and filtering systems. It is typically used with systems that handle a large amount of information (Brusilovsky and Millán, 2007).

Goals

The learner's goals answer the question of what a learner wants to achieve from the adaptive e-learning system. Goals can be classified into ***short-term*** and ***long-term***. ***Long-term*** goals can be a long-term plan for lifelong study whereas ***short-term*** goals are directed towards solving a certain problem such as doing an exercise (Nguyen and Do, 2008). Goals can be represented using the *goal catalogue* approach. In this approach, a list of pre-defined goals and tasks is included. This list can be, in its simple form, a small list of independent goals or can be in a hierarchical form (Brusilovsky and Millán, 2007).

Demographic Information

Some adaptive e-learning systems use learner's demographic information to perform adaptation. This information might include gender, culture and age (Ghaban, 2020; Nguyen and Do, 2008).

Personal Traits

The learner's personal traits determine a range of characteristics that together define a learner as an individual such as learning styles, cognitive styles and personality traits (Brusilovsky and Millán, 2007; Brusilovsky, 2001; Nguyen and Do, 2008). Similarly to the learner's background, these traits are stable and do not change or change slowly. However, they differ from the learner's background in the way they are extracted. Typically, special designed psychological tests are used (Brusilovsky and Millán, 2007; Brusilovsky, 2001).

- **Cognitive style:** determines the user's preferred way of organising and processing information and experience (Brusilovsky and Millán, 2007; Sadler-Smith, 2001). It is also defined as the learner's preferred way to perceive and undertake problem-solving, thinking, remembering and creativity (Isaksen et al., 2003; Riding and Cheema, 1991). Different dimensions exist in the literature to differentiate between learner's cognitive styles (Brusilovsky and Millán, 2007; Sadler-Smith, 2001). These dimensions are divided into two fundamental cognitive style families; wholist-analytic dimension and verbaliser-imager dimension. In the first dimension, the learner tends to process and organise the information in whole or in parts whereas they tend to represent the information during thinking, in the second style, verbally or visually (Riding and Cheema, 1991; Sadler-Smith, 2001)
- **Learning style:** determines the preferable way of learning. It is narrower than the cognitive style as it focuses on the learner's learning (Brusilovsky and Millán, 2007). More precisely, learning style refers to the learning preferences that impact the way of perceiving, gathering and processing the learning materials. For example, some learners prefer audio materials while others prefer graphical or textual representation (Chrysafiadi and Virvou, 2013). Different

learning style models exist in the literature to identify the learner's learning style. The Felder-Silverman learning style is one of the most popular models adopted by many Intelligent Tutoring Systems. It categorises the learners into four dimensions (Alshammari, 2016; Felder et al., 1988):

- *Active/Reflective*: determines the preferred way of **processing** the information. Active learners learn by exploring things and interacting with peers while reflective learners learn by thinking deeply before acting.
- *Sensing/Intuiting*: determines the preferred **type** of information. Sensory learners prefer concrete information such as facts while intuitive learners prefer abstract concepts such as theories.
- *Visual/Verbal*: determines the preferred way of **presenting** the information. Visual learners prefer information in a pictorial format such as charts and diagrams while verbal learners prefer information in textual or audio formats.
- *Sequential/Global*: determines the preferred way of **structuring** the information. Sequential learners prefer to learn in linear, logical steps until they get the big picture of the lesson while global learners prefer to be provided with the big picture and the objective of the lesson before the steps are introduced.

In contrast, other researchers do not believe in learning styles. (Kirschner, 2017) argued that there are some problems with the concept of learning styles: (1) the preferable way of learning is not a learning style, (2) learning styles classify learners into groups which received very little support from objective studies and (3) most studies which present evidence for learning styles fail to meet all major criteria of scientific validity. In addition, (Riener and Willingham, 2010) believe that learners differ in their abilities, backgrounds, knowledge and interests but not in their learning styles. Learners may prefer to learn in a certain way but there is no strong evidence that suggests considering these preferences will lead to effective learning. However, the information should be presented in an appropriate manner for the content taking into account the knowledge level, ability and interest of the learner.

- **Personality traits:** determine a set of characteristics that affect an individual's feeling, thinking, interaction and communication with others (Ghaban, 2020). Different models have been used to describe and classify personality. The most widely used and stable model is the Big Five model or the Five-Factor Model. This model classifies the personality traits into (Mattheiss et al., 2017):

  1. *Extraversion*: the tendency to be outgoing, seek new opportunities and be ambitious.

Individuals, who have a high score in this trait, are described as excited, confident, energetic and talkative.

2. *Conscientiousness*: the tendency to be well-organised and self-disciplined. Individuals, who have a high score in this trait, follow rules and prioritise tasks.
3. *Neuroticism*: the tendency to be emotionally unstable. Individuals, who have a high score in this trait, are nervous, sensitive and unable to manage stress.
4. *Agreeableness*: the tendency to be considerate and cooperative. Individuals, who have a high score in this trait, are caring, helpful and prefer to cooperate over compete.
5. *Openness*: the tendency to be imaginative and creative. Individuals, who have a high score in this trait, are adventurers, explorative and open to trying new things.

The relationship between the previous three personal traits (cognitive style, learning style and personality traits) is illustrated using the ***Onion model*** developed by (Curry, 1983) as shown in Figure 3.4. The outer layer is the most observable layer and interacts directly with the learning environment. This layer reflects the way a learner prefers to learn which is the learning style. The middle layer reflects the information processing which is the cognitive style. Finally, the inner layer is the cognitive personality layer that reflects the personality trait of an individual.

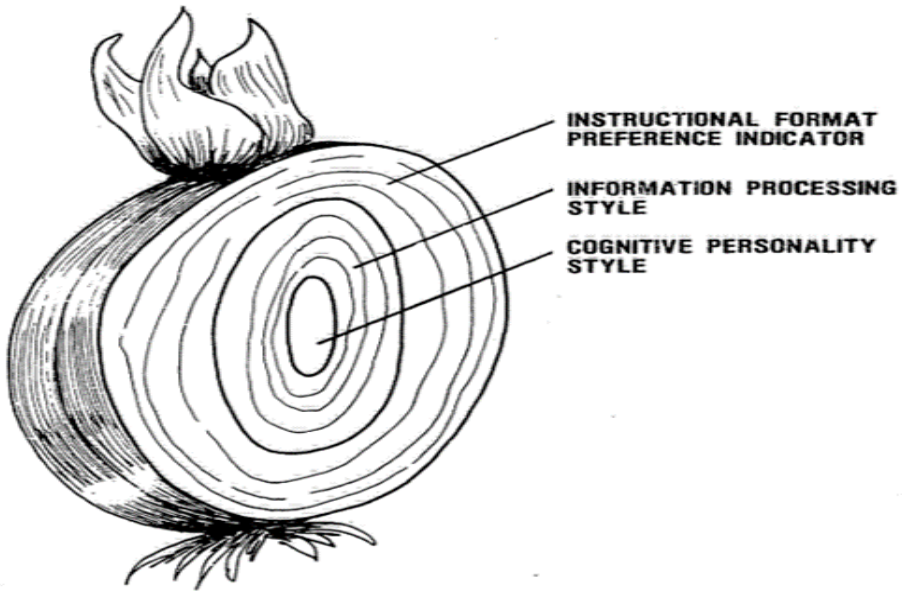


Figure 3.4: Onion Model Layers (Curry, 1983)

These characteristics are relevant to all types of learners. However, there are special cases of learners with unique characteristics such as dyslexia, dysgraphia or ADHD. As dyslexia is the focus of this research, one of its particular characteristics, adopted here, is its reading difficulties which have been classified into dyslexia types (Friedmann and Haddad-Hanna, 2014; Friedmann and Coltheart, 2016) as mentioned in Section 2.3.4.

Dyslexia types have not been widely considered in the existing research as a characteristic in the learner model. As detailed in Chapter 2, dyslexia is a lifelong reading difficulty that barely changes so it is stable but the severity of dyslexia may change over time. Further, dyslexia types are the mirror of dyslexia reading difficulties which identify dyslexia and therefore, can be considered one of the dyslexia personal traits.

Learner Model Representation

This stage describes the way of modelling and presenting the chosen learner characteristics in the learner model. Different models are used for this purpose such as the overlay model and stereotype model (Alshammari et al., 2014; Chrysafiadi and Virvou, 2013).

The ***overlay model*** is one of the most frequently used models that assumes a learner has partial but correct information of the domain (Chrysafiadi and Virvou, 2013). Thus, it represents the learner model as a subset of the domain model. It is widely used to represent the learner's knowledge level simply and effectively (Alshammari et al., 2014; Brusilovsky and Millán, 2007; Nguyen and Do, 2008; Chrysafiadi and Virvou, 2013). In this model, the domain is divided into fragments and the learner's knowledge level for each domain fragment is estimated. The early form of the overlay model used a Boolean value, yes or no, to indicate whether a learner knows this knowledge or not. Later, a qualitative value (such as good, average and poor) was used to indicate the degree of learner's knowledge level (Brusilovsky and Millán, 2007; Chrysafiadi and Virvou, 2013). Unfortunately, the overlay model cannot represent either the incorrect knowledge that a learner acquired or the learner's behaviour and preferences. Therefore, the overlay model is used with other models (Alshammari et al., 2014; Chrysafiadi and Virvou, 2013) to increase the efficiency and accuracy of the learner model.

The ***stereotype model*** is one of the oldest and commonly used models in learner modelling (Brusilovsky and Millán, 2007; Chrysafiadi and Virvou, 2013). It classifies the learners who share certain attributes such as preferences, learning styles, backgrounds, interests and behaviour into groups known as ***stereotypes*** (Brusilovsky and Millán, 2007; Alshammari et al., 2014; Nguyen and Do, 2008; Chrysafiadi and Virvou, 2013). A user will be assigned to one of the predefined stereotypes if some of that user's attributes match those in that stereotype (Chrysafiadi and Virvou, 2013). Stereotype is often classified into ***default*** and ***fix***. In the ***fix*** stereotype, the learner is assigned to a predefined stereotype permanently whereas, in the ***default*** stereotype, they are assigned to an initial stereotype which then can be changed through the learning process based on the system's observation. A stereotype typically contains three components; trigger, inference and retraction. The ***trigger*** component is a condition that activates a stereotype by assigning a stereotype to a learner. The ***inference*** component is an inferring engine that infers from a

stereotype, information about the learner. ***Retraction*** component are conditions that deactivates a stereotype from a learner (Nguyen and Do, 2008). This model is useful to quickly initialise the learner model. However, it may end up with learners who cannot be matched to the pre-defined stereotypes (Alshammari et al., 2014; Chrysafiadi and Virvou, 2013).

Learner Model Elicitation

This stage describes the way of identifying the learner's characteristics. Two different approaches are used to gather the learner's characteristics which are then used for building the learner model: ***explicit*** approach and ***implicit*** approach. In the ***explicit*** approach, the learner is asked directly and explicitly via ratings, surveys, questionnaires and even interviews to get feedback about, for example, their knowledge and interests. Other reliable tests can be used to determine the learners' traits (Ghaban, 2020; Zigoris and Zhang, 2006; Alshammari, 2016). For instance, determining the learner's preferred learning style by using the learning style inventory tool (Alshammari, 2016). The explicit approach is more reliable and accurate than the implicit one. In the explicit approach, the learners put in extra effort as they need to answer questions or give feedback on certain items (Zigoris and Zhang, 2006).

On the other hand, in the ***implicit*** approach, the learners' characteristics are collected implicitly. They are collected easily without any extra effort from the learner. For instance, tracking the number of clicks on a specific page or the clicks on arrow keys and time spent on a certain page (Zigoris and Zhang, 2006).

Once the required learners' characteristics are collected, they are combined and analysed to construct a learner model which is then used to generate the adaptive version for each individual learner. Analysing these characteristics can be performed manually or automatically. In the former, the learners' characteristic is analysed manually whereas, in the latter, the learners' characteristic is fed into a machine learning algorithm for automatic analysis (Ghaban, 2020).

3.3.2.2 Domain Model

The domain model represents the e-learning content. It includes two parts; domain structure and content. The structure is usually modelled using abstract representations of units of information. It also includes both concept relationships such as preconditions and results and how pieces of information relate to concepts and how they are stored. The content of the domain contains both the information units such as text documents and images and a description of how they are stored and invoked (Vassileva, 2012).

In short, the domain model consists of concepts and relations between these concepts related to a specific domain (Knutov et al., 2009; Ding et al., 2018; Brusilovsky, 2012; Alshammari et al., 2014). These concepts are a set of small domain knowledge elements. Each domain knowledge element

represents a primary fragment of the domain knowledge (Alshammari et al., 2014; Brusilovsky, 2012). Domain knowledge element may have different synonyms in different systems such as learning objectives, learning outcomes and topics (Brusilovsky, 2012).

Different techniques can be used to structure the domain model. The simplest technique is representing the domain model as a set of unconnected domain knowledge elements. This is known as a ***set model*** or a ***vector model*** (Brusilovsky and Millán, 2007; Brusilovsky, 2012). The main drawback of this technique, once a specific domain knowledge element is linked to the learner model, is the difficulty of moving to the next domain knowledge element (Ghaban, 2020). This issue was addressed in ***tree*** and ***network*** models where the domain knowledge elements are interconnected. In the ***tree model***, a tree of educational objectives is formed and gradually decomposed into smaller domain knowledge elements. The more popular model is the ***network model*** where the domain knowledge elements are connected using different types of links forming a complex network. The most common links are known as **prerequisite** links. These links represent the fact that one related domain knowledge element must be learned before the other (Brusilovsky and Millán, 2007; Brusilovsky, 2012).

3.3.2.3 Adaptation Model

The adaptation model is the core element that provides adaptation (Ding et al., 2018) through a collection of rules and functions which specifies the adaptation process (De Bra and Ruiter, 2001; Mustafa and Sharif, 2011). This collection helps in selecting the appropriate pedagogical materials from the domain model and determining the time and way to deliver them (Ennouamani and Mahani, 2017). This model bridges the gap between the learner and domain models by matching the learner's attributes and learning material (Alshammari et al., 2014; Mustafa and Sharif, 2011). Different ways can be used to provide the adaptation effect to the e-learning systems using what is called adaptation technologies (Aroyo et al., 2006; Brusilovsky, 1999). Among these technologies are adaptive presentation and adaptive navigation support (Brusilovsky, 1999) (see Figure 3.5).

Adaptive Presentation Technology: presents the most relevant information to the learner based on their knowledge level, goals and other learner model characteristics (Brusilovsky, 1999; Aroyo et al., 2006; Brusilovsky, 1998). In short, it determines what information is shown to the learner (Ding et al., 2018). For instance, the system can suggest reading part of its content (*adaptive text presentation*) (Knutov et al., 2009) or choose the most suitable content format (text, audio and image) for presentation according to, for instance, learner learning style (*adaptation of modality*) (Brusilovsky, 2001).

Adaptive Navigation Support Technology: determines the learner's navigation path according to their knowledge, goals and other learner model characteristics (Ding et al., 2018; Brusilovsky,

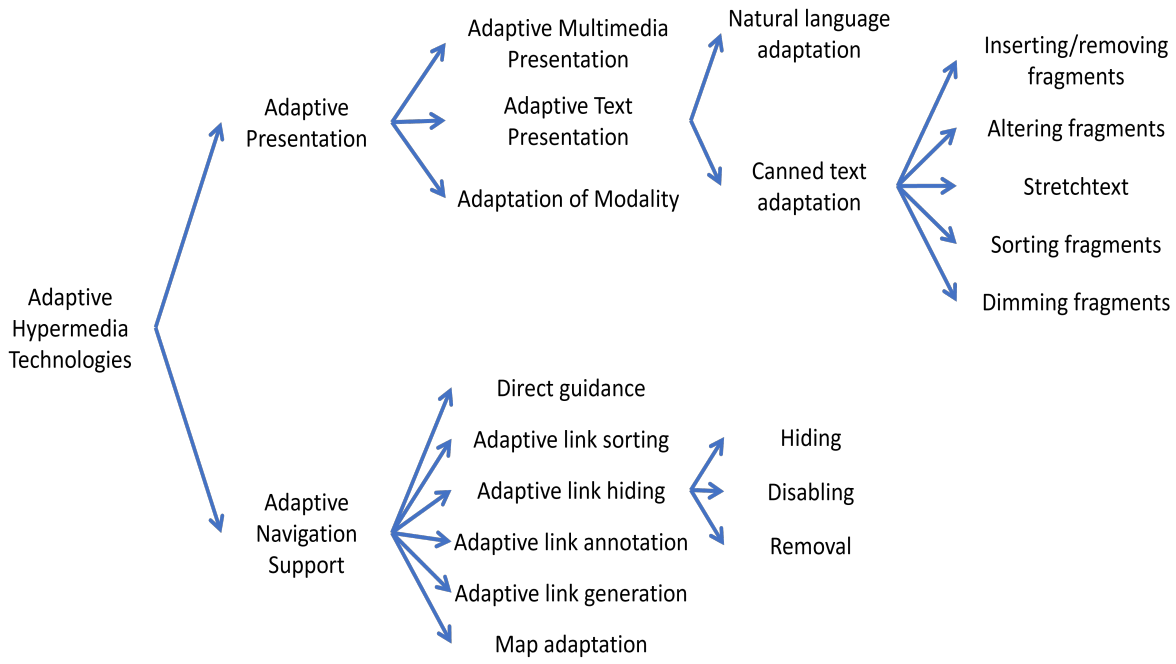


Figure 3.5: The Updated Taxonomy of Adaptive Hypermedia Technologies (Brusilovsky, 2001)

1998). Precisely, the learner is guided towards the relevant information by playing with the visible links to support their navigation (Aroyo et al., 2006; Brusilovsky and Pesin, 1995; Brusilovsky, 1999). The learner's navigation can be either enforced or suggested (see Figure 3.6). The guidance techniques fall in the first case where the learner is forced to select a link from computed links by either hiding irrelevant links or generating a directed navigation path. The second case is preferred by most adaptive navigation research where a number of links are suggested to the learner over others. In this case, the learner is not forced to follow these links. A list of links can be sorted starting from the strongest recommendation or can be annotated using colours or icons to help the learner decide on the appropriate links (Knutov et al., 2009).

Among adaptive navigation support techniques, direct guidance, adaptive link annotation and adaptive link hiding are the most popular in adaptive e-learning systems (Brusilovsky, 1999). In *direct guidance*, the system decides the next best link for the learner to follow according to the learner's parameters in the learner model (Brusilovsky, 1998, 2007, 1999). In *adaptive link annotation*, the system provides the learner with the current node's state by augmenting it with dynamic comments (Brusilovsky, 1998, 2007; Brusilovsky and Pesin, 1995). These annotations can be text-based or pictorial. The pictorial annotations can be icons, colours or font sizes (Brusilovsky, 1998, 2007). Finally, the system, that uses *adaptive link hiding*, hides the irrelevant links according to, for instance, the learner model attributes (such as the learner's current goals) by hiding, removing or disabling such links (Brusilovsky, 1998, 2007). e-Teacher is a system that has used the adaptive navigation support technology by guiding the learner through a course according to their

characteristics in the learner model and their current stage within the course (Schiaffino et al., 2008).

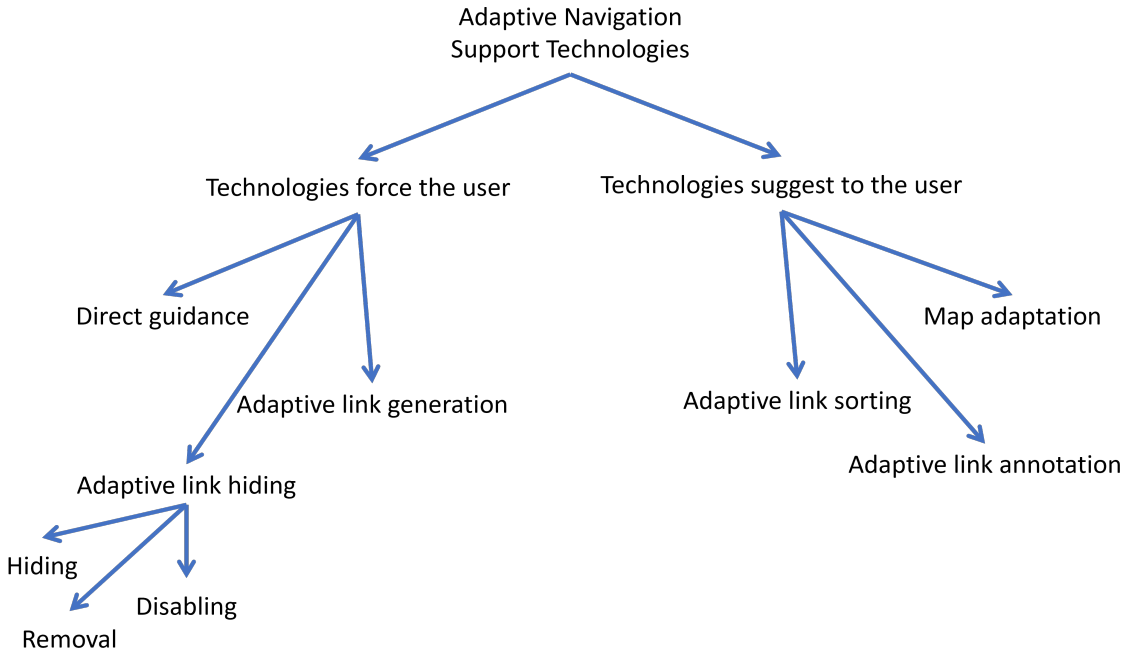


Figure 3.6: Classification of Adaptive Navigation Support Based on Forcing or Suggesting to Learner

To conclude, the adaptation process is a challenging, nontrivial task. It is achieved by the adaptation model which cannot be isolated from the other models. The data stored in these models (learner and domain) are required to trigger the adaptation model. So, the key challenge to developing an effective adaptive e-learning system is to determine both the learner characteristics that will be used in the adaptation process along with the part of the system that will be affected by the adaptation. Further, the most suitable adaptation technique should also be determined as well as the time of providing the adaptation.

3.3.3 Evaluating Adaptive E-learning Systems

The spread of adaptive e-learning systems demonstrates the need to evaluate the effectiveness of such systems. Evaluating adaptive e-learning systems is a complicated task (Paramythis et al., 2010; Gena, 2005) but is an important issue because it determines the worth of that system (Worthen et al., 1997). Adaptive e-learning systems should be accurately evaluated in order to correctly measure the effectiveness of the learning process (Shute and Towle, 2003). There are a variety of evaluation approaches in the literature to evaluate adaptive systems which can be classified based on their goals into ***formative*** and ***summative*** evaluations (Paramythis et al., 2010). The formative evaluation aims to explore the early-stage design issues (Triantafillou et al., 2003) in order to improve the system design and development whereas the summative evaluation, which is often

based on learner assessments, aims to determine the extent to which a learner model was accurate or the extent to which the applied adaptation methods has improved the adaptive e-learning system (Paramythis et al., 2010).

Different approaches can be used to evaluate adaptive systems. One approach is using ***formative evaluation*** to evaluate, for instance, the effectiveness of the system's instruction (Triantafillou et al., 2003). Another approach is ***collecting learners' opinions*** using, for instance, a questionnaire as in (Esichaikul et al., 2011) that evaluated, in general, the system's usability. Other tools can also be used to obtain learner opinions such as interviews and focus groups (Gena, 2005). A third approach is ***observing and monitoring usage*** such as observing the learning paths that the learners follow in the adaptive e-learning system (Van Seters et al., 2012). A final approach to mention is evaluating the system using an ***experimental evaluation***. This approach evaluates the effectiveness and usability of adaptive e-learning systems in a structured setting to reflect real-world situations (Alshammari, 2016). It helps in estimating the benefits of adaptation and may prove/disprove the success of the chosen adaptation decision. Several studies have used the experimental evaluation approach to evaluate the effectiveness of their adaptive e-learning systems. One study conducted by (Bajraktarevic et al., 2003) to measure the achievement differences between matched and mismatched sessions of learning material with the same group of learners. Other studies measured achievement differences between matched and mismatched groups instead such as (Alghabban et al., 2021; Al-Dawsari and Hendley, 2021; Fatahi, 2019). Usability issues were also considered in studies conducted by (Alshammari et al., 2015a; Alghabban and Hendley, 2021) where the former considered the learning style and knowledge level in the adaptation process whereas the latter considered dyslexia types.

Different metrics have been used to evaluate adaptive e-learning systems. Among these metrics are learning gain and learner satisfaction. Each one is explained below.

Learning Gain: The effectiveness of the learning is a key factor when evaluating adaptive e-learning systems (Alghabban and Hendley, 2022). Learning gain, computed using pre- and post-tests, is typically used to reflect the improvement level in the learner's knowledge after using a particular intervention. To assess learning gain, the pre-test is used to group the learners based on their knowledge level. Two balanced groups of learners are created; one group interacts with the adaptive version of the system whereas the other group interacts with the non-adaptive version. If the first group scores higher in their learning gain than the second group, the adaptation is successful (Gena, 2005).

In the case of learners with dyslexia, it is important to evaluate the adaptive e-learning systems based on their needs by assessing their learning gain. Previous research has explored this and found

that adaptive e-learning systems have succeeded in improving the learning gain of learners with dyslexia as seen in (Alghabban et al., 2021; Alghabban and Hendley, 2020a).

Another important outcome in education, is assessing the generalisation performance which is assessing the learner's ability to generalise learned content to other contexts (Nist and Joseph, 2008). However, the generalisation performance is rarely assessed. Generalisation performance can be considered as another metric to evaluate the effectiveness of adaptive e-learning systems. It can be measured using pre- and post-tests that differ systematically in terms of similarity with the material used in the adaptive e-learning system (Alghabban and Hendley, 2022).

Learner Satisfaction: Learner satisfaction plays an important role in the learning process, therefore, it is an important metric for evaluating the effectiveness of the e-learning system (Alshammari et al., 2015d; Alakkas, 2016; Siritongthaworn and Krairit, 2006). According to (Gatian, 1994), the learner satisfaction is considered a valid predictor for the effectiveness of the system. Satisfaction refers to the pleasure that a user feels when they do something or receive something that they needed. In the Human-Computer Interaction (HCI) field, user satisfaction is usually conceptualised as an expression of feelings acquired from interaction (Shee and Wang, 2008). In e-learning, learner satisfaction can refer to the learner's motivation and engagement in the learning process. It also can show to what extent the system fits the needs of the learner (Alshammari et al., 2015d; Alakkas, 2016; Siritongthaworn and Krairit, 2006). To assess the learner satisfaction, interviews can be used, after interacting with the system, to obtain learner opinions that reflect their satisfaction with that system (Gena, 2005). The post-test questionnaire can also be used for such an assessment by asking questions to the learners about their satisfaction with the system they used (Alghabban and Hendley, 2022). There are many tools that can be used to measure satisfaction such as (Jung, 2014; Wang, 2003; Bailey and Pearson, 1983). Among these tools, the satisfaction in e-learning questionnaire tool (Siritongthaworn and Krairit, 2006) is a reliable and validated tool to assess the learner satisfaction with the e-learning system, especially if that system is used as a supplementary tool to the classroom teaching instead of being the main method of instruction delivery as in (Wang, 2003). It contains 15 questions categorised into four dimensions: delivery method, communication facilitation, system operations, and content with an extra question to measure the overall satisfaction. These items have a 5-point Likert scale ranging from 1 "strongly disagree" to 5 "strongly agree".

In the case of children, using the original 5-point Likert scale in its verbal form is not useful as it is difficult for them to understand and interpret and thus choose the appropriate response (Read and MacFarlane, 2006). One widely used alternative scale is the ***Smileyometer***, as shown in Figure 3.7. It is ranked from one to five and codes the responses from awful to brilliant in a pictorial

format (Sim et al., 2006). The good thing about the Smileyometer is that it is easy to use because it can be completed quickly, easily, without writing and requires limited reading (Read, 2008). In this scale, the children can identify their feelings towards the system by selecting one face.



Figure 3.7: Smileyometer

In the case of learners with dyslexia, it is useful to assess their degree of satisfaction with the system. It provides an indirect measurement of the suitability of the system to their needs. These learners will be satisfied with the system if it meets their needs and characteristics which in turn will positively affect the effectiveness of the learning (Alghabban and Hendley, 2020b).

Obviously, there are different approaches to evaluating different aspects of the adaptive e-learning system using different metrics to accomplish a particular goal. Therefore, to properly evaluate adaptive e-learning systems, the evaluation goal should be identified in order to choose the appropriate evaluation approach and metrics. This leads to well-reported results and to proper conclusions.

3.3.4 Examples of Adaptive E-learning Systems

There are different examples of adaptive e-learning systems proposed in the literature that have used different learner characteristics to provide adaptation. For instance, the learner's **knowledge level** was used by *ANATOM-TUTOR* and *C-Book* systems to adapt the learning material of anatomy and C programming language respectively. Both systems used the adaptive text presentation technique (Beaumont, 1994; Brusilovsky, 1998; Kay and Kummerfeld, 1994a). The *ANATOM-TUTOR* system hides pieces of the information about a specific concept that is irrelevant to the learner's knowledge level about that concept whereas the *C-Book* system provides all prerequisite concepts that are new to the learner before presenting the required concept (Brusilovsky, 1998; Kay and Kummerfeld, 1994b). *ELM-ART*, another adaptive educational system, also used the learner's **knowledge level** to adapt the LISP Programming content using adaptive annotation and adaptive link sorting techniques (Brusilovsky et al., 1996; Weber and Brusilovsky, 2016). However, *ISIS-Tutor* system used both learner's **knowledge level** and **educational goals** to provide adaptation. It provides the print formatting language of the ISIS information retrieval system by using direct guidance, adaptive link hiding and annotation techniques. It hides the nodes that are irrelevant to the current educational goal (Brusilovsky, 1998). Additionally, colour annotations were used to lead from current links to related links based on the learner's knowledge and educational goals

(Brusilovsky and Pesin, 1995).

The **learning style** was another learner characteristic that is used to provide adaptation such as the adaptive educational systems proposed by (Alshammari et al., 2015d) and (Kolekar et al., 2018). The former adapts computer security teaching according to the learner's learning style by using the link generation technique to provide the adaptation process (Alshammari et al., 2015d) whereas the latter (Kolekar et al., 2018) proposed an adaptive educational system based on the Moodle framework that adapts the learning material of a Java programming language course according to the learner's learning style. It used the adaptation of modality approach to provide the adaptation process.

The previous examples of adaptive e-learning systems targeted the characteristics of normal learners. There are other examples that targeted the characteristics of learners with dyslexia. For example, the **dyslexia learning style** was used to provide adaptation by (Benmarrakchi et al., 2017b) who 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 students' 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, the number of participants was small and thus its effectiveness is not guaranteed.

The **dyslexia types** was another characteristic for learners with dyslexia that is used to provide adaptation such as (Alghabban and Hendley, 2020b) who investigated how personalising learning material based on **dyslexia types** affects children's satisfaction. An adaptive e-learning system was implemented to improve the reading performance of children in elementary schools. The system was evaluated by a controlled experimental study. The results showed that children with dyslexia were more engaged with their learning experience when the learning content was matched to their dyslexia type. However, the learning performance and effectiveness were not considered in this study.

Another study was conducted by (Alghabban and Hendley, 2021) who considered the dyslexia **reading skill level** in the adaptation process to evaluate an adaptive Arabic educational system in terms of usability. They found that learners with Arabic dyslexia were more satisfied with the e-learning system when its learning material was adapted to their reading skill level.

Other adaptive e-learning systems used a combination of two characteristics such as (Alsobhi and Alyoubi, 2020) who suggested adapting the learning material of adaptive educational systems according to both **dyslexia learning style** and **dyslexia types**. As a start, they studied the

relationship between the four dimensions of the Felder-Silverman learning style model and dyslexia types of the Dyslexia Symptoms and Classification Model. Most of the learners with dyslexia were visual learners. However, the proposed system lacks evaluation in terms of learning gain.

One last example to mention is the proposal of (Hamid et al., 2015) who preferred the adaptation technique by developing an adaptive computer-based learning model based on learners' needs to help them in learning the Malay language. This model considered both the cognitive and emotional difficulties that learners with dyslexia may face. The study also explored the uses of the machine learning approach in order to improve the effectiveness of learning. Unfortunately, they did not mention the learner characteristic that is used to provide adaptation and the model has not been tested and therefore its effectiveness is uncertain.

3.4 Conclusion

Building adaptive e-learning systems is a nontrivial, challenging and complicated task. Most adaptive e-learning systems contain three models (learner, domain, adaptation) that should be well-designed to provide effective adaptation. The most important model that has a significant impact on the adaptation process is the learner model. Learner characteristics, used as a source of adaptation, must be accurately identified and elicited using reliable tools and the impact of adaptation, according to these characteristics, must be deeply understood before building a complete adaptation model. Therefore, this research seeks to understand the impact of adaptation on learners with Arabic dyslexia according to their characteristics, for instance, their Arabic dyslexia types. To do so, the different interventions to help individuals with dyslexia have been reviewed and analysed in Section 2.4 and Section 3.3.4 to capture their limitations and the issues that should be considered. In the case of this research, the technological interventions are highlighted. From the analysis, four major limitations have been explored:

- Very little work has been driven by the theoretical model of the reading process.
- The majority of research treated individuals with dyslexia as a single class while research has pointed out that they are each different. In other words, most of the proposed interventions directed to dyslexia have treated them as a single group and not different groups.
- Lack of well-designed controlled experiments and unclear hypotheses.
- Where evaluations have been undertaken, they have a small number of participants and thus no statistically significant results have been found and no conclusions can be drawn from these results.

Additionally, five issues have been captured and should be considered when designing a technological intervention to support dyslexia:

- **Goal**: is the intervention intended to help individuals with dyslexia to read better or to cope with their difficulties?
- **Domain**: what skill(s) do(es) the intervention target?
- **Language**: each language has a different structure and orthography and therefore affects the manifestation of dyslexia which in turn affects the interventions targeted to individuals with dyslexia.
- **Age**: the age of individuals with dyslexia impacts the intervention. Dealing with a 5 year old child, for instance, is not the same as dealing with those in higher education.
- **Evaluation**: what aspects of the intervention will be evaluated (measurements)? Measuring learning improvement after using an intervention, for instance, is different from measuring usability. Once the measurements are determined, how will this aspect be measured? Using tests, for instance, or questionnaires.

The previous limitations and issues are discussed in detail in the following sub-sections.

3.4.1 Design

Most of the technological interventions reviewed suffer from a number of design issues that must be overcome in our research:

- They were designed based on data-driven practice rather than on a particular theory. Specifically, these interventions were designed based on practice rather than a theoretical model such as the reading model (Al-Abdulkarim et al., 2010; Benmarrakchi et al., 2017a; El Kah and Lakhouaja, 2018). However, designing an intervention based on a theoretical model may offer a number of benefits because theory guides the design of the intervention by understanding the main problem that the intervention will target and then choosing the goal that the intervention seeks to achieve. This leads to a well-designed intervention, which in turn enables the results to be discussed effectively. However, this does not mean that taking benefit from practice is useless. Some teachers, who teach students with dyslexia, have used practices that do not relate to any theoretical model and produced promising results. Therefore, it may be best to design an intervention based on both theory and practice (by using data from the real world).

- They treated all individuals with dyslexia similarly such as the research of (Al-Abdulkarim et al., 2010; Gooch et al., 2016; Vasalou et al., 2017; El Kah and Lakhouaja, 2018; Alsobhi and Abeysinghe, 2013) while these individuals differed according to their symptoms and the difficulties they face. However, once the interventions considered the differences between individuals with dyslexia, such as considering their preferences in the working environment by adapting that environment to their preferred text presentation (page format, text and background colour), the group of individuals with dyslexia who may benefit from this type of adaptation has not been determined and therefore the results have not been properly discussed.

- Their hypotheses were unclear which resulted in poor methodologies.

- They lack rigorous controlled experiments and if they were conducted, they were not evaluated effectively by for example evaluating the proposed intervention with real learners as in the case of (Al-Abdulkarim et al., 2010; Alsobhi et al., 2015a; Hamid et al., 2015; Benmarrakchi et al., 2017a).

3.4.2 Goal

In the aforementioned research, the proposed interventions to support individuals with dyslexia addressed different goals. These goals are (1) learning support as in (Al-Abdulkarim et al., 2010), (2) training support as in (Martins et al., 2016) and (3) assistive support as in (Lukeš, 2015). The ***learning support*** aims to teach an individual with dyslexia a new concept by, for example, presenting an explanation of that concept in different modes (text, audio, video) and supporting it with examples. For instance, teaching individuals with dyslexia a new reading skill. The ***training support*** aims to provide additional exercises on an already known concept. For example, training individuals with dyslexia on an already known (taught) spelling skill by providing extra exercises on that skill. Finally, the ***assistive support*** is intended to help individuals with dyslexia overcome their difficulties such as using the spelling checker to overcome and compensate for their spelling errors. Because of the different goals that each intervention may target, it is critical to choose the appropriate goal as it will influence the design of the intervention.

3.4.3 Domain

As mentioned earlier, individuals with dyslexia face different difficulties in different domains such as difficulties in reading, writing, spelling and mathematics, as well as they may face behavioural difficulties such as low levels of self-esteem. It is essential to choose the domain of the intervention because it will influence the design of the learning content. For instance, if the reading domain is

chosen, then the learning content will be designed to focus on teaching reading which, obviously will be different from teaching spelling.

3.4.4 Language

Since dyslexia is about difficulty with words, another important issue to consider when designing an intervention is which language to target. In fact, languages differ in terms of the alphabet, grammar, being cursive or not, reading direction, including regular and/or irregular words, consistent or inconsistent orthography, etc. Therefore, different difficulties appear in individuals with dyslexia while others disappear accordingly. Actually, improving the literacy skills of dyslexia depends mainly on the language of learning.

In the research reviewed, different languages such as English (Lukeš, 2015), Malay (Hamid et al., 2015), Finnish (Lyytinen et al., 2007) and Spanish (Rello et al., 2014) were studied. Obviously, some of these languages are consistent while others are not. It is easier to learn consistent languages for individuals with dyslexia than inconsistent ones because of the direct connection between the letter and its phoneme.

3.4.5 Participants

Another important issue to consider is the number of participants and their characteristics that will influence the design of the intervention such as age and gender. As this research targets learners with dyslexia, then their dyslexia type should be considered as it also affects the design of the intervention.

- Number: the number of participants was small in the previous research (Gooch et al., 2016; Benmarrakchi et al., 2017b; El Kah and Lakhouaja, 2018) and therefore no statistically significant results were found and no conclusions were drawn. So, the number of participants must be adequate to analyse the results effectively.

- Age: dealing with participants in Kindergarten, primary school, high school or even university is different from one another. For instance, a primary school may provide a whole spectrum of individuals while a university may provide only the most intelligent individuals. Therefore, each age group has its own characteristics, which once identified, will help to consider these characteristics and design the appropriate intervention for that age group.

- Gender: determining the gender of the participants may be useful. Males may respond differently to the intervention than females. Unfortunately, the previous research reviewed such as (Kolekar et al., 2018) did not take this aspect into account and thus most of the proposed interventions were used by participants regardless of their gender. Further, the

gender of the participant may influence the design of the interface and/or the content of the intervention.

- Dyslexia type: this research targets dyslexia and therefore the participants must be formally diagnosed with dyslexia and their dyslexia type must be identified. It is critical to identify their dyslexia type in order to address the difficulties they face and then design the appropriate intervention for them.

3.4.6 Evaluation

Each intervention can be evaluated from different aspects using different measurements. For example, measuring the learning effect of an intervention on the student through pre- and post-tests before and after using that intervention.

After reviewing, analysing and identifying the limitations of the previous interventions and highlighting the issues that need to be considered when designing an intervention, this research will consider these limitations and issues. Details are provided in the next chapter along with the overall framework of this research.

Chapter 4

Understanding The Impact of Adaptation on Learners with Arabic Dyslexia

4.1 Introduction

The previous chapter discussed adaptive e-learning systems in terms of the concept and the models that make up this system. It was clear that building an adaptive model is complex and, especially the learner model, must rely on reliable tools to extract the learner's characteristics required for adaptation. Further, the effect of adaptation must be well understood and produce promising results before building an effective adaptive model.

To our knowledge, there are insufficient studies to explore the effect of adaptation on learners with Arabic dyslexia and therefore, it is impossible to build an effective adaptive model without investigation of the effect of adaptation. Consequently, this research seeks to understand the impact of adaptation on learners with Arabic dyslexia. More precisely, we want to understand whether adapting e-learning content based on Arabic dyslexia types improves the learners' learning. In this chapter, we present the overall framework and methodology for this research.

4.2 Motivation

Since learners with Arabic dyslexia have different reading problems from those in other languages and each learner faces their own reading problems, it is important to provide each learner with appropriate support that takes into account their individual needs by adapting e-learning systems. As this research targets adaptive e-learning systems for learners with Arabic dyslexia and unfortunately, few studies have explored this area, we cannot build an effective adaptation model for these learners before understanding the impact on them of adaptation. Therefore, we seek to:

Understand the impact of adapting the training material of an e-learning system to Arabic dyslexia types on the learner's reading, satisfaction and behaviour.

This research considered the limitations and issues found in previous research, which were detailed in the previous chapter as follows:

- **Design:** The experiments in this research were designed based on a combination of the dual-route model for single-word reading (theoretical model) and practice. According to this theoretical model, learners with Arabic dyslexia were categorised into different groups (Arabic dyslexia types) which were targeted by this research. This led to providing clear hypotheses and designing well-controlled experiments.
- **Goal:** The goal of this research is to understand the effect of adaptation on learners' reading, satisfaction and behaviour.
- **Domain:** According to the previous point, the reading skill was chosen to be the domain of the experiments.
- **Language:** Due to the limited research on the Arabic language and a large number of native Arabic speakers, the experiments targeted this language.
- **Participants:** The participants were primary school learners with Arabic dyslexia with one of the two Arabic dyslexia types targeted in each experiment in this research.
- **Evaluation:** The experiments were evaluated by identifying the metrics to be measured and the tools for measuring them in order to discuss the results effectively. Here, learning gain and learner satisfaction were measured using tests and a questionnaire.

To achieve the aim of this research, three controlled experiments were conducted with different e-training materials and Arabic dyslexia types. The effect of adaptation on learner's reading and satisfaction was measured using learning gain and learner satisfaction. The learners' behaviour was also observed. An overview of these experiments is provided in the following section.

4.3 Overview of Experiments

There are different learner characteristics that can be used to drive adaptation such as personality and learning style. In this work, the Arabic dyslexia type was chosen. It is a special characteristic of learners with Arabic dyslexia. According to (Friedmann and Haddad-Hanna, 2014), there are seven Arabic dyslexia types known in the literature. The frequency of each Arabic dyslexia type

among learners with Arabic dyslexia was calculated as shown in Table 2.2. For practical reasons, this research targeted the two most frequent Arabic dyslexia types: letter position dyslexia and vowel letter dyslexia. Then, the dyslexia diagnostic test was designed to determine the Arabic dyslexia type of the learner as detailed in Section 4.5.2.

So, to understand the impact of adapting the training material to learner's Arabic dyslexia type on their reading performance, satisfaction and behaviour, a series of controlled experiments were conducted. Each experiment targeted two Arabic dyslexia types. Hence, different training material was embedded within the e-learning system for each experiment.

Experiment One, originally, targeted vowel letter dyslexia and letter position dyslexia to understand the impact of matching the training material to learners with vowel letter dyslexia on their reading performance compared to learners with letter position dyslexia. The training material in this experiment targeted vowel letter dyslexia. The control group was learners with letter position dyslexia while the experimental group was learners with vowel letter dyslexia. Unfortunately, while conducting the first experiment, letter position dyslexia did not appear among learners with Arabic dyslexia at Saudi primary schools in Riyadh. So, this type should be replaced by another common dyslexia reading problem among these learners. This was done by searching for this reading problem among the learners with Arabic dyslexia in primary schools in Riyadh. That is why the mistakes of these learners in the dyslexia diagnostic test were analysed. Mixing the phonemes of the three essential short vowels (diacritical marks) in a word was another common reading mistake among these learners and this was confirmed by the special education teachers. This reading mistake was named short vowel dyslexia and used instead of letter position dyslexia in the research. Experiment One targeted short vowel dyslexia and vowel letter dyslexia. The control group became learners with short vowel dyslexia. Details of this experiment are covered in Chapter 5.

The contradiction between what was found in practice and what was published by (Friedmann and Haddad-Hanna, 2014) in terms of the frequency of Arabic dyslexia types could be due to the location where the research was conducted (KSA). The research of (Friedmann and Haddad-Hanna, 2014) was conducted in Palestine which has a different dialect from KSA, especially Riyadh city. This provides evidence of what (AlRowais et al., 2013) stated, that different dialects affect the manifestation of dyslexia.

To complement Experiment One, Experiment Two matched the training material to learners with short vowel dyslexia instead of learners with vowel letter dyslexia. That is, this experiment targeted the same two Arabic dyslexia types: short vowel dyslexia and vowel letter dyslexia, but it switched their positions. The control group became learners with vowel letter dyslexia and the experimental group became learners with short vowel dyslexia. Now, the training material matched short vowel

dyslexia instead of vowel letter dyslexia. Details of this experiment are covered in Chapter 6.

Both experiments were pilot studies to validate the training materials, system, tools and experimental design in order to refine our approach for the final and main experiment. Once the data in these experiments were analysed, surprising results were found. There was no statistically significant difference in either learning gain or learner satisfaction between the experimental group and the control group in either experiments.

The first and second experiments were designed based on our understanding of the difficulties faced by learners with Arabic dyslexia from a literary point of view. But we have found that what has been published in the literature does not quite match what we have found in practice, with evidence that letter position dyslexia is mentioned in the literature as a common Arabic dyslexia type, and practice has denied this. In addition, we have found that what is found in practice does not also quite match the literature, as evidenced by the fact that short vowel dyslexia is common in practice, which is not mentioned in the literature. From this point of view, we have found it necessary to understand the difficulties faced by these learners from the expert's point of view who are special education teachers, and then to combine the literature with practice.

So, an exploratory questionnaire was designed and published to special education teachers. This was to explore the field and to understand the difficulties faced by learners with Arabic dyslexia from the perspective of special education teachers. Details of this questionnaire in terms of the design process, results, analysis and discussions are provided in Chapter 7.

The questionnaire revealed a number of results. The most important was finding another common Arabic dyslexia type (in addition to vowel letter dyslexia); visual dyslexia. So, the last experiment targeted vowel letter dyslexia and visual dyslexia. Its aim was still to understand the impact of adapting the training material to Arabic dyslexia types on learners' reading performance. The control group became a non-adaptive group and the experimental group became an adaptive group. The adaptive group was exposed to an adaptive version of the e-learning system while the non-adaptive group interacted with the non-adaptive version. The adaptive version provided training material that is adapted to the learner's Arabic dyslexia type (vowel letter dyslexia or visual dyslexia) while the non-adaptive version provided non-adapted generic training material. More details of this experiment are covered in Chapter 8.

The hypotheses tested in these experiments are presented in the next section.

4.4 Hypotheses

Several hypotheses were formulated to test the research's aim. It was hypothesised that providing training material adapted to the needs of learners with Arabic dyslexia has an overall benefit,

especially in short-term learning gain and satisfaction.

In this research three controlled experiments were conducted. The first two experiments tested two hypotheses while the last experiment tested four hypotheses. In Experiment One, the training material was matched to vowel letter dyslexia using the matched/mismatched experimental design. Therefore, these hypotheses were tested:

> **H1.1:** Matching training material to learners with Arabic vowel letter dyslexia achieves significantly greater learning gain compared to learners with Arabic short vowel dyslexia.

> **H1.2:** Matching training material to learners with Arabic vowel letter dyslexia achieves significantly greater learner satisfaction compared to learners with Arabic short vowel dyslexia.

In Experiment Two, the training material was matched to short vowel dyslexia, to complement the previous hypotheses, which led to another two further hypotheses:

> **H2.1:** Matching training material to learners with Arabic short vowel dyslexia achieves significantly greater learning gain compared to learners with Arabic vowel letter dyslexia.

> **H2.2:** Matching training material to learners with Arabic short vowel dyslexia achieves significantly greater learner satisfaction compared to learners with Arabic vowel letter dyslexia.

Once the previous hypotheses were tested, there were no statistically significant results in either measurements; learning gain and learner satisfaction, and thus they were rejected. According to the results of the questionnaire, the last experiment replaced short vowel dyslexia with visual dyslexia and targeted both vowel letter dyslexia and visual dyslexia using an adaptive/non-adaptive experimental design. In this experiment, the learner's ability to generalise learned content to other contexts was also tested. This is achieved by measuring the learning gain of unseen words in both conditions. Now, these hypotheses were tested:

> **H3.1:** Adapting training material to learners' Arabic dyslexia type achieves significantly greater learning gain compared to non-adapted material.

> **H3.2:** Adapting training material to learners' Arabic dyslexia type achieves significantly greater learning gain of seen words compared to non-adapted material.

> **H3.3:** Adapting training material to learners' Arabic dyslexia type achieves significantly greater learning gain of unseen words compared to non-adapted material.

H3.4: Adapting training material to learners' Arabic dyslexia type achieves significantly greater learner satisfaction compared to non-adapted material.

4.5 Design

To conduct the research, three controlled experiments were designed and developed. In each experiment, an e-learning system was developed and a number of tools were used. The system and the tools are presented in the following sub-sections.

These experiments followed the between-subjects experimental design. In a between-subjects design, the participant experiences only one condition of the experiment while in the within-subject design, the participant experiences two different conditions. The former is more appropriate for this research (Alshammari et al., 2014), because a learning effect might be carried from one condition to another. In contrast, more participants are needed in the between-subjects design which might raise noise and variations that will affect the results. These should be explained or eliminated before drawing conclusions (Alshammari, 2016).

In all experiments, participants were divided into two groups: an experimental group and a control group. The first two experiments used the matched/mismatched groups design where the experimental group represents the matched group and the control group represents the mismatched group. Both groups used the same version of the system with different training material used in each experiment. In the first experiment, the training material matched the vowel letter dyslexia whereas, in the second experiment, the training material matched the short vowel dyslexia. Further, the designed system and tools were validated in these two experiments. The framework for these two experiments is shown in Figure 4.1.

The last experiment used the adaptive/non-adaptive groups design where the experimental group represented the adaptive group and the control group represented the non-adaptive group. Here, the experimental group used the adaptive version of the system whereas the control group used the non-adaptive version. The adaptive version provides training material that is adapted to the learners' Arabic dyslexia type while the non-adaptive version provides training material that is not adaptive. The framework of this experiment is shown in Figure 4.2. The procedure of the entire research is presented in Section 4.7.

4.5.1 DysTypeTrain E-learning System

To conduct the experiments, we designed and implemented a dynamic web-based e-learning system, named ***DysTypeTrain*** (`http://arab-dyslexia-learning.com/`). Its interface is shown in Figure 4.3. ***DysTypeTrain*** was implemented to train learners with Arabic dyslexia via eight reading sessions where each contained ten activities giving a total of 80 activities. The difficulty of these ac-

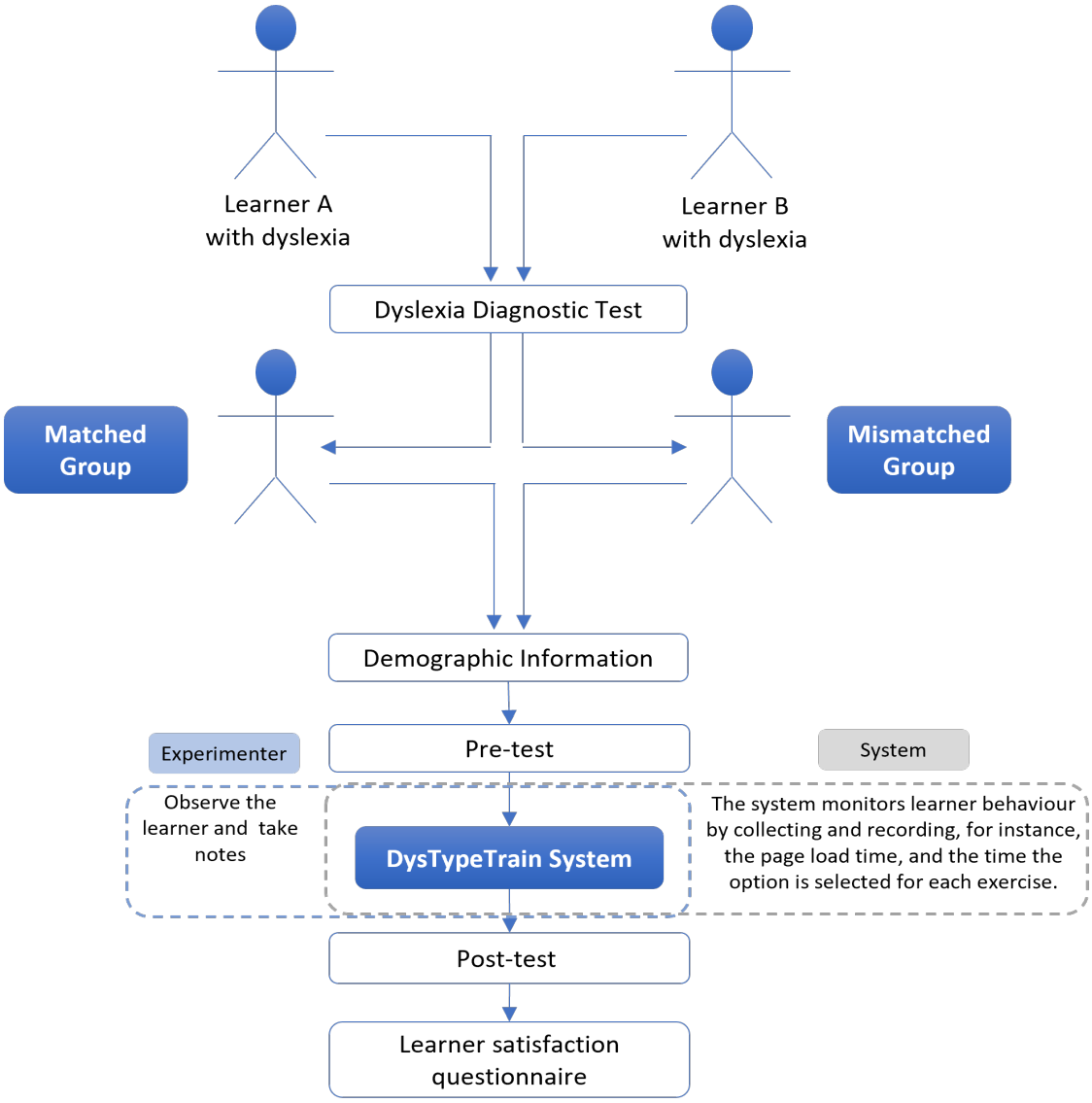


Figure 4.1: Framework of Experiments 1 and 2

tivities gradually increased. Since most learners with dyslexia have the same profile in preferring to use visuospatial/kinesthetic style (Exley, 2003), (Benmarrakchi et al., 2017a) recommended using a multi-sensory approach. For each activity, the system pronounces a word and displays its corresponding image along with three choices. Each choice displays a different word. The learner listens to the spoken word (question) and should choose the correct choice. If the learner chooses a correct answer, then the system gives encouraging positive feedback (Benmarrakchi et al., 2017a), and they gain a point (Dymora and Niemiec, 2019). Otherwise, the system gives remedial feedback. The system also presents the total point score on the screen and provides feedback on training progress in the form of activity number (between 1 and 10) at the top of the screen, as shown in Figure 4.3. In addition, the system enables the learner to re-play the question, as many times as they want, by clicking on the audio icon presented on the screen and they can use the displayed image as a hint. The layout of the training sessions was consistent; that is keeping the audio icon, the image

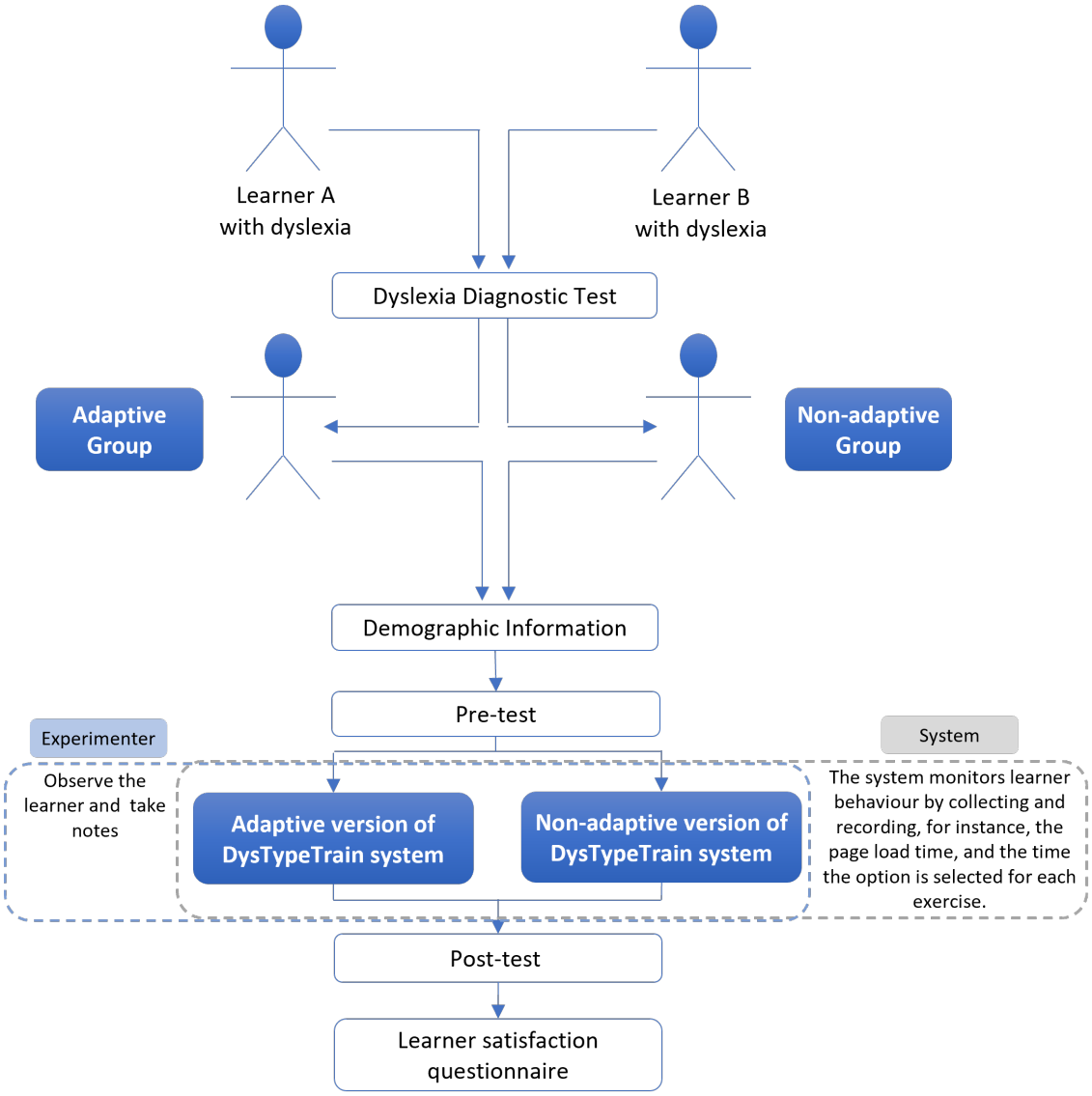


Figure 4.2: Framework of Experiment 3

and all three choices in the same place. These training sessions only differ in the training material that they provide. More details about the system are given in the following sub-sections.

Framework: The framework of the system used in this research is illustrated in Figure 4.4. This framework includes:

- **Domain Model**: which represents the content of the e-learning system.
- **Learner Model**: which represents the characteristics of the learner that are used in the adaptation process.
- **Adaptation Model**: which uses the previous two models to adapt the e-learning system.
- **Auxiliary Components**: These are:
  - **Interaction Data Modeller**: which monitors the interactions between the learner and the system to feed it, in our case, into the learner model to be updated.

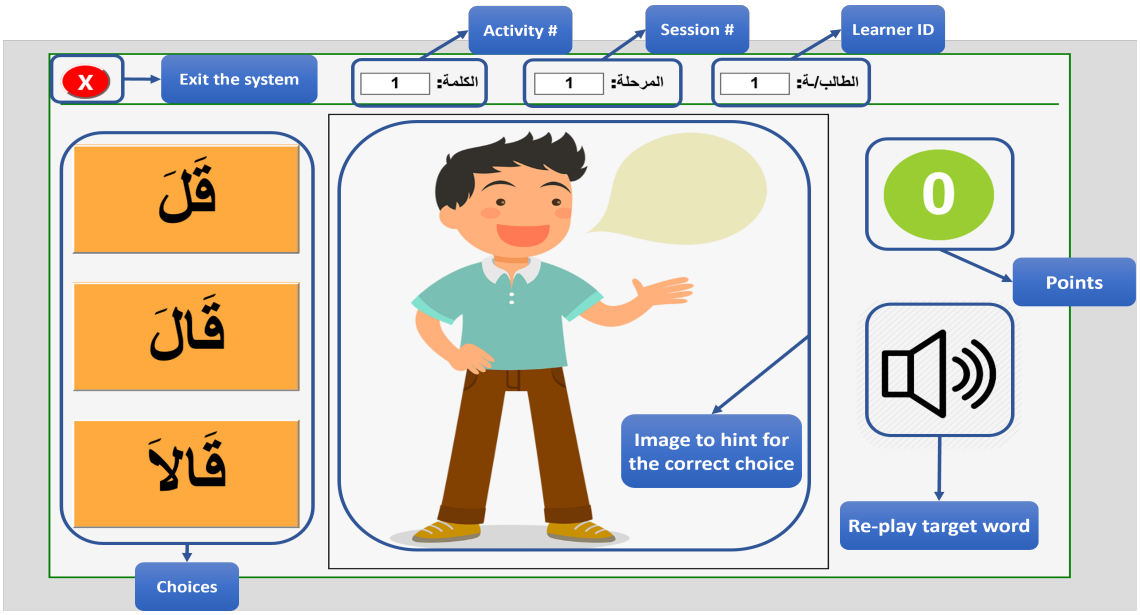


Figure 4.3: ***DysTypeTrain*** System Interface

– **Interface**: which facilitates the interaction between the system and the learner.

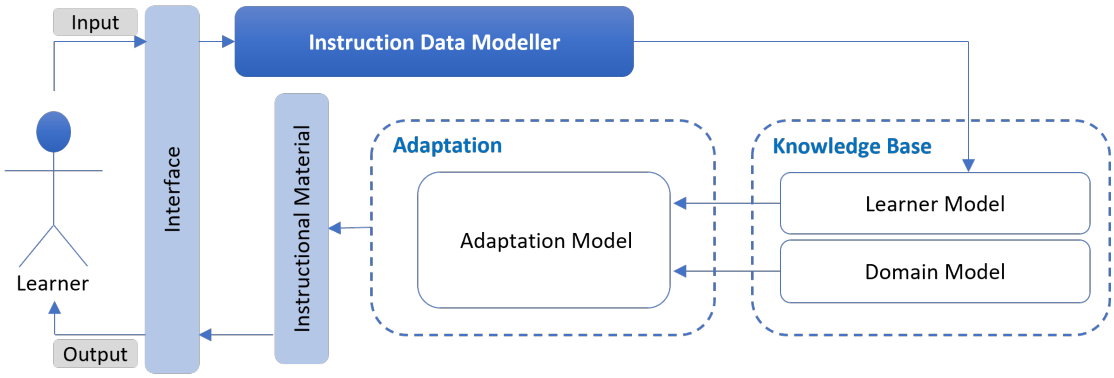


Figure 4.4: Updated Version of The Adaptive E-learning Framework (Alshammari et al., 2015b)

Architecture: The previous framework was used to build the ***DysTypeTrain*** system architecture. The architecture of ***DysTypeTrain*** is a three-tier client/server architecture as shown in Figure 4.5. This architecture divides the components of ***DysTypeTrain*** into three layers of services: client, server and storage. The **client tier** contains the system interface through which the learner can register in the system and interact with the training material provided by this system. Learner actions with the interface are sent to the server tier. For instance, If the learner makes a specific choice, it will be sent to the server tier to handle.

The **server tier** contains the *interaction data modeller* and the *business logic*. The *interaction data modeller* takes learner actions with the interface from the client tier and feeds them into the learner model in the storage tier to be updated. For instance, once a learner selects an option in the last exercise of a particular session, the *interaction data modeller* will compute the total score

for the learner in that exercise and store the completion status of that session along with the calculated score in the learner model. The *business logic* uses the macro-adaptive approach (an adaptive learning approach that provides adaptation based on a predefined static learner characteristic (Ennouamani and Mahani, 2017)) to provide (static) adaptation by selecting the appropriate training material from the domain model according to the predefined characteristic, Arabic dyslexia type, in the learner model to be presented in the system interface at the client tier. The macro-adaptive approach was used because the aim of the research is to understand the impact of adaptation and not to build an effective adaptive model. Further, the *business logic* keeps the exercise number that the learner interacts with, to move to the next exercise, once the current one is completed.

The **storage tier** contains the database that holds the learner model and domain model. The learner model stores the learner characteristics, such as demographic information (age, gender, grade, initial reading level), score of each completed session, and the learner's Arabic dyslexia type that was identified through an offline dyslexia diagnostic test and fed manually into the learner model. The domain model contains the training material of the ***DysTypeTrain*** system in various forms; text, image and audio.

The domain model is represented in the ***DysTypeTrain*** system using the network model because the exercises in the training material are ordered where the learner cannot move to the next exercise before completing the current exercise. The learner model is represented using the stereotype model because the learners are grouped into stereotypes which are in our case the Arabic dyslexia types. Adaptation is provided using the adaptive content technique (Stern and Woolf, 2000) where the training material that matches the learner's Arabic dyslexia type is presented in the system interface.

The ***DysTypeTrain*** system was implemented in the NetBeans development environment. NetBeans[1] is an open-source integrated development environment (IDE) that is used by many developers and users. It supports many programming languages and enables coding, running, testing and deploying different types of software applications. In this environment, the HTML5 markup language was used to design the interface of the ***DysTypeTrain*** system.

The functionality of the ***DysTypeTrain*** system was written using the server-side scripting language Hypertext Pre-Processor (PHP) [2]. PHP is widely used for developing web applications to generate dynamic content. The object-oriented programming style is supported by PHP to facilitate creating more compact and effective code by grouping related operations on objects into specific classes.

Training material and the learner characteristics and progress in the e-learning system were repre-

[1] `https://netbeans.org/`
[2] `https://www.php.net/`

sented, stored, encrypted, retrieved and maintained along with any data relating to the learner's interaction with the system in a secure database. MySQL[3] was used to facilitate database creation and management. It is an open-source relational database management system (DBMS) compatible with PHP.

Once the design of the ***DysTypeTrain*** system was completed, Bluehost[4] was used to provide web hosting and make the system accessible on the Internet by renting space on their physical server to store all data and files of the ***DysTypeTrain*** system. It also protects all data with encrypted connections.

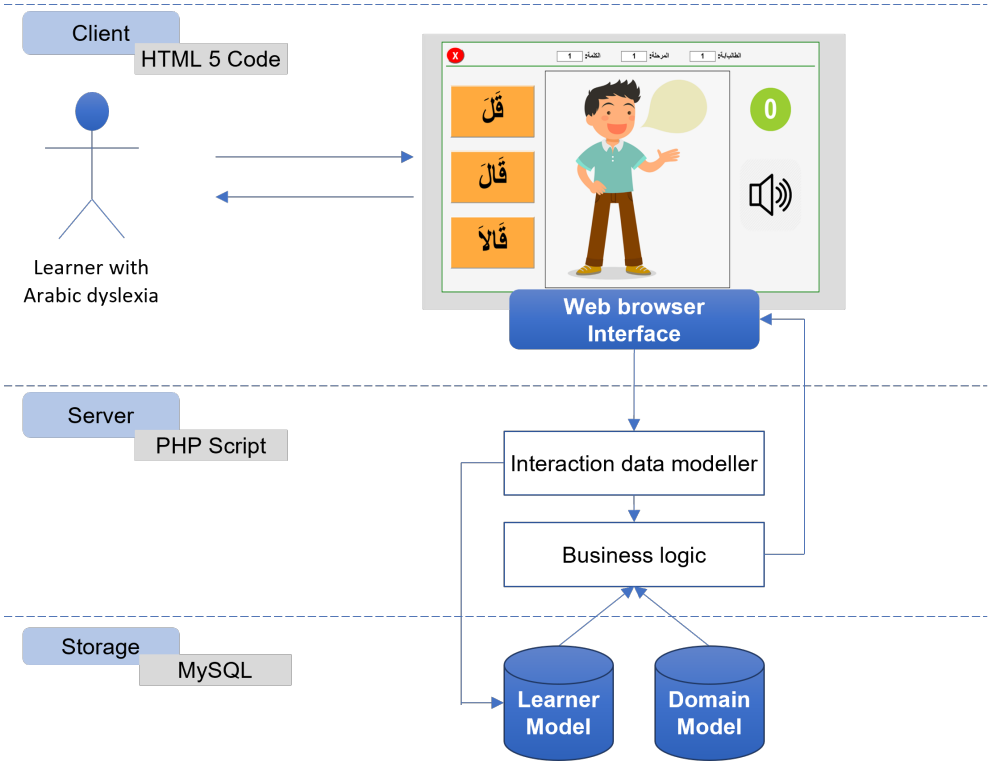


Figure 4.5: ***DysTypeTrain*** System Architecture

Training Material: The training material was chosen from the academic textbooks of Saudi primary school to target the reading problems of the chosen Arabic dyslexia types (vowel letter dyslexia, short vowel dyslexia, visual dyslexia). The training material was designed following the cognitive theory of multimedia learning. The underlying design draws on dual coding theory, cognitive load theory and constructivist theory (Mayer and Moreno, 2002; Benmarrakchi et al., 2017b). According to (Mayer and Moreno, 2002), the following five instructional design principles were considered when designing the training material of the ***DysTypeTrain*** system:

- **Multimedia aids**: Represent the training material using both words (as narration) and pictures.

[3] https://www.mysql.com/
[4] https://www.bluehost.com/

- **Contiguity aids**: Represent the training material using both words (as narration) and pictures simultaneously.
- **Coherence aids**: Exclude extraneous words and sounds from the training material.
- **Modality aids**: Represent the words in the training material as spoken text instead of on-screen text to reduce the load on the visual channel for deeper cognitive processing.
- **Redundancy aids**: Represent the training material using only animation and narration and avoid using on-screen text which could overload the visual working memory.

As shown in Figure 4.6, the training material is divided into four main reading topics where each topic is also divided into two reading sessions and each session included 10 activities with which the learner interacts.

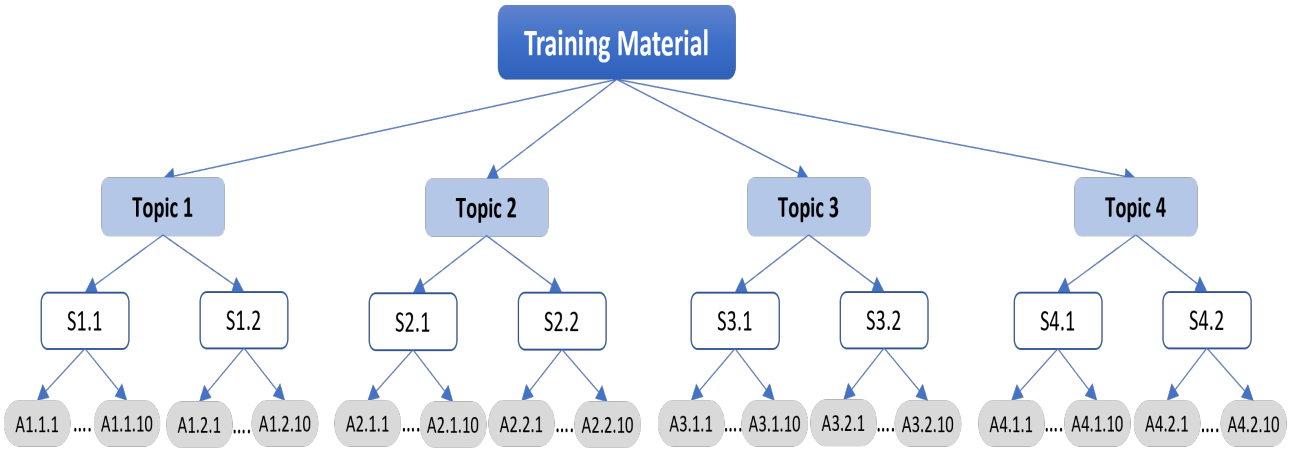


Figure 4.6: Training Material Structure in ***DysTypeTrain*** System (S=Session, A=Activity)

Interface: The interface of ***DysTypeTrain*** system was designed following the guidelines suggested by (Al-Wabil et al., 2006) for web design accessibility of Arabic content:

- **Text size**: Use the range of 16-20 points. Sixteen points was used as a minimum text size.
- **Font type**: Use Arabic Transparent or Simplified Arabic Fixed Font. The Simplified Arabic Fixed font was used.
- **Font colour**: Use high contrast colours between text and background. Black text on either a light grey or orange background was used.
- **Background**: Avoid dark backgrounds. The background colour used was light grey.
- **Emphasizing text**: Avoid using italic or underline and use bold or a combination of bold and colour instead. The latter was used.
- **Diacritization**: Use diacritics to improve both reading accuracy and comprehension especially for beginners and poor readers. As this research targets learners with Arabic dyslexia

in primary schools to improve their reading, the diacritics were used in the training material.

4.5.2 Tools

In addition to the e-learning system described above, five more tools were used when running the three experiments:

- **Consent Form**: This form was used to obtain the school's and parents' consent for their children to participate in the experiment because they are under 18 years old. The form introduced the experiment, explained its methodology, withdrawal policy and time duration, the benefits for the children and also indicated that the data collected were anonymised (see Appendix A).
- **Dyslexia Diagnostic Test**: This is a reading test conducted with learners with Arabic dyslexia. It was used to determine their Arabic dyslexia type. It focuses on two Arabic dyslexia types depending on the Arabic dyslexia types that the experiment is targeting. In the first and second experiments, the test focused on vowel letter dyslexia and short vowel dyslexia whereas it focused on vowel letter dyslexia and visual dyslexia in the last experiment (see Appendix B). After taking the test, it is determined whether the learner can participate in the experiment or not. The learners who can participate in the experiments are those diagnosed with one of the target Arabic dyslexia types. Learners who cannot participate are those who have been diagnosed with both Arabic dyslexia types (at a similar level of severity) or have none of the target Arabic dyslexia types (i.e. have other Arabic dyslexia types). The test was validated by:
  - Building the test upon the official diagnostic test for determining the type of learning difficulty (not Arabic dyslexia type) published on the Saudi Ministry of Education website. The diagnostic test was designed to determine two Arabic dyslexia types. It includes two sections and each section includes 10 words for the learner to read. Each section targets an Arabic dyslexia type according to the Arabic dyslexia type that the experiment is targeting.
  - Reviewing and validating the test with special education teachers.
  - Comparing the learners' results of the test with the assessment of their special education teachers because (1) there is no reliable diagnostic test in the literature determining the Arabic dyslexia type of the learner and (2) the teacher is the only person who communicates directly with the learner and knows exactly what their reading problems are and therefore knows their Arabic dyslexia type.

- **Structured Interview**: This interview was conducted with special education teachers to gather the demographic information of their learners with Arabic dyslexia participating in the experiment. This information included the demographic information of the learner (age, gender, grade), reading problems and non-reading problems based on the teacher's assessment which is used to validate the results of the dyslexia diagnostic test as mentioned earlier (see Appendix C).
- **Pre- and Post-tests**: The pre-test was used to measure the initial reading level of the learner before using the e-learning system. The post-test was conducted immediately after using the system in the last experimental session. The pre-test score was used to balance the two groups of learners in each experiment. Then, both pre- and immediate post-test results were used to measure the learner's short-term learning gain score which is used as a proxy for the learner's reading improvement. These tests were identical for each experiment and included 10 words targeting the training material for that experiment (see Appendix D).
- **Learner Satisfaction Questionnaire**: This questionnaire is used to measure the learner satisfaction with the e-learning system. Because the learners are children, their satisfaction was collected by taking their opinions about the system after using it. This questionnaire was supported with a Smileyometer (see Figure 3.7) (Appendix E). As the learners were highly satisfied with the system in the first and second experiments, their satisfaction was measured in more detail to determine the reason for this high level of satisfaction. Therefore, in the third experiment, the satisfaction in e-learning questionnaire was used (Siritongthaworn and Krairit, 2006) (Appendix E). It contained 10 questions to assess the content, systems, delivery method and overall satisfaction. This questionnaire was used for the following reasons:

  - Its role corresponds to that of ***DysTypeTrain*** system, that the e-learning is voluntary and supplementary (Siritongthaworn and Krairit, 2006).
  - It covers all satisfaction aspects necessary for this experiment including the content of the e-learning system that is targeted by this research.
  - It is a 5-point Likert scale questionnaire that can be adapted to the Smileyometer due to learners' young age.

4.6 Participants

Learners with Arabic dyslexia were the participants in all three experiments. They were diagnosed with vowel letter dyslexia, short vowel dyslexia or visual dyslexia. These learners were at different primary schools in Kingdom of Saudi Arabia (KSA) (from second grade to sixth grade). First grade

learners were not included because they were new to the school and had just started learning to read, so it was unknown to their teachers whether or not they had dyslexia.

This age group of learners was chosen because it is easily accessible. High school learners were difficult to access due to the large number of classes they attend weekly. In universities, unfortunately, there were very few learners who were known to have dyslexia. Therefore, these other age groups were not suitable. Restricting the age group also provides more control over the experiments by recruiting only primary school learners.

Primary schools were visited to obtain their consent for conducting the experiments. Then, parental consent forms were sent to parents on behalf of their children because they are under 18. Participants were aware that they could withdraw from the experiment at any time. The role of these participants in all experiments was:

- Conducting the dyslexia diagnostic test, pre- and post-tests.
- Interacting with ***DysTypeTrain*** system for eight experimental sessions.
- Filling out the learner satisfaction questionnaire.

4.7 Procedure

Once the ethical approval from schools, parents and learners was obtained, the practical part of the research started. It is composed of three different experiments. All three experiments were conducted in KSA. Due to COVID-19, which led to schools' closure, part of the first two experiments were conducted face-to-face while the other part was conducted remotely using Zoom meetings and MS Teams. The last experiment was conducted entirely remotely. The participants were registered to the system by following this procedure:

- The learners were diagnosed using the dyslexia diagnostic test to determine their Arabic dyslexia type.
- The learners who were diagnosed with the targeted Arabic dyslexia types became participants for the experiment. Others were excluded.
- The demographic information, reading and non-reading difficulties of these participants were collected via interviewing their special education teachers.
- The participants were welcomed and introduced to the goals of the experiment. Then, they took a pre-test to determine their initial reading level. After that, the participants were registered to the system.

After registration was completed, the three experiments were conducted consecutively. In each

experiment, participants were divided into two groups (experimental and control), balanced in the number of learners, Arabic dyslexia type, age, and initial reading level. In the first two experiments, both experimental (matched) and control (mismatched) groups used the same version of the system as shown in Figure 4.1. In the last experiment, the experimental (adaptive) group used the adaptive version of the system whereas the control (non-adaptive) group used the non-adaptive version as shown in Figure 4.2.

Experiments were conducted either in person or remotely in the presence of the experimenter, in a quiet room. Only the participant was in the room. The participant sat in front of a desk with either a smartphone or laptop to interact with the ***DysTypeTrain*** system while the experimenter observed them either in person or through the camera of their smartphone/laptop and resolved any technical issues. Participants worked with the system on their own, without any assistance, during eight experimental sessions. Two sessions per week were conducted for each participant. Each session lasted for approximately 35 minutes. At the beginning of the first session, the experimenter explained the layout of the system interface. During each session, the participants were observed by the experimenter and notes were taken about their interaction with the system and their facial expressions. Neither the experimenter nor the participant was aware of the experimental condition to which the participant was assigned. After completing the experiment, the participants were asked to take the post-test and to fill out the learner satisfaction questionnaire.

The data of all participants: usernames, passwords, pre- and post-test scores and satisfaction scores were stored in the database. The participants' progress was tracked through the e-learning system and also stored in the database.

4.8 Data Collection

All three experiments in the research used a mixed-methods approach in which both quantitative and qualitative data were collected. Quantitative data were collected to measure the learner's learning gain and satisfaction whereas qualitative data were used to monitor the learner's behaviour while interacting with the system. Both data types are presented in detail in the following sub-sections. It is worth noting that there was an attempt to measure reading speed in the last experiment. Unfortunately, because the sessions were conducted remotely, two issues appeared:

- Poor Internet connection at the participant's side.
- Participants were distracted by their families.

These problems (from the participant's side) led to a delay in making the choice and/or reading the pre- and post-tests. As a result, the accuracy of the reading speed measurement was negatively

affected and cannot be guaranteed.

4.8.1 Quantitative Data

Quantitative data were collected in the form of pre- and post-tests and the learner satisfaction scores which were then used to measure both the learner's learning gain and satisfaction. These data were statistically analysed using IBM SPSS Statistics software with standard condition $p < 0.05$ for significant results (Andrade, 2019).

Learning Gain Since the main aim of the research is to examine the impact of adapting the training material to Arabic dyslexia type on the learner's reading, their reading level was measured before and after using the e-learning system.

The amount of reading improvement for each learner was measured by calculating their learning gain as follows:

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Learner's Learning Gain = Learner's Post-test Score - Learner's Pre-test Score
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After calculations were completed, the data was analysed to find out if there is a statistically significant difference in the learning gain between the experimental and control groups. The analysis, results and discussions are provided for each experiment separately in Chapters 5, 6 and 8.

Learner Satisfaction The second measurement in this research used to assess both the effectiveness of the system and the effect of adaptation is learner satisfaction. It is measured to determine whether the learners were satisfied with the adapted training material more than the non-adapted one. Precisely, learner satisfaction was measured to determine whether the learners were aware of the appropriateness of the training material for them. So, learner satisfaction provides an indirect way of understanding the effect of adaptation. The tools that were used to measure learner satisfaction were reported in Section 4.5.2 (Appendix E).

4.8.2 Qualitative Data

Qualitative data were collected by the experimenter while observing each learner in each session. For privacy reasons, the sessions are not video recorded, therefore, the observations were collected from the notes taken by the experimenter. During the observation process, the way each learner interacted with the system was recorded. This included taking notes on their verbal and non-verbal (facial) expressions. Facial expressions included happiness, sadness, engagement and boredom. Happiness and sadness are identified by the schematic faces shown in (Gao and Maurer, 2009) whereas boredom denotes a lack of interest and loss of attention resulting in eye closure and lack of mouth movements such as opening and closing the mouth and jaw drop (Kim et al., 2018; Craig et al., 2004). Engagement is determined by staying on the task without any admonition (Whitehill

et al., 2014).

These observations were analysed using the Thematic Content Analysis method, following the approach given by (Braun and Clarke, 2006). In this method, codes (and sub-codes if needed) are generated from data collected from observations. They are created gradually one by one starting from the first observation and ending on the last one. Then, the codes are grouped into themes (and sometimes sub-themes) and theoretical concepts. These codes must be related to each other within a theme and the themes must also be related to each other and to the entire data set.

4.9 Research Ethics

- The entire research followed the procedure of the ethics review at the University of Birmingham (Appendix F).
- The researcher took the consent of all parents to enable their children to participate in the experiments because they were underage.
- The results of the learners in the dyslexia diagnostic test, pre- and post-tests were anonymised in a way that neither the researcher nor the teachers could identify these learners. This data was encrypted and stored securely in a database.
- The researcher took the consent of all interviewees. They were informed about the aim of the interview and the way their data will be used. The interview data were anonymised in such a way that the respondents themselves and the learners they were referring to in the interview could not be identified.

4.10 Conclusion

Most research treated individuals with dyslexia as a single category. This conflicted with what has been published in the literature, where dyslexia can be classified into different types. One of these classifications, adopted by this research, was based on the dual-route model of a single-word reading which identified different classes of dyslexia. Each class should be treated differently by using adaptation technology. Further, due to the limited research on Arabic dyslexia, this research aimed to understand the impact of adapting the content of an e-learning system to Arabic dyslexia types on learner's reading performance, satisfaction and behaviour. The entire methodology and framework for this research were presented in this chapter. To achieve the aim of this research, three controlled experiments were conducted. The first experiment is detailed in the next chapter while the other two experiments are detailed in Chapters 6 and 8, respectively.

Chapter 5

Matching Training Material to Learners with Arabic Vowel Letter Dyslexia

5.1 Introduction

Chapter 4 presented the framework of this research, which aims to understand the effect of adapting the training material to the learner's Arabic dyslexia type on learner's reading performance, satisfaction and behaviour, and the methodology used to conduct the three experiments of this research. Only two out of seven Arabic dyslexia types were targeted in each experiment to understand the effect of adaptation for practical reasons; time limitations, more control over the experiment and the limited number of learners with Arabic dyslexia with the other Arabic dyslexia types. The first experiment targeted vowel letter dyslexia and short vowel dyslexia as they are common among the learners, according to the literature and practice. It studied the impact of matching the training material to vowel letter dyslexia on the learner's learning. Details of this experiment and results are introduced in this chapter.

5.2 Experiment One

Experiment One was conducted as a pilot in order to (1) understand the effect of matching the training material to learners with vowel letter dyslexia on their reading performance, satisfaction and behaviour and (2) validate the developed system and tools used in this experiment. As mentioned in Section 4.5.1, a dynamic web-based e-learning system, ***DysTypeTrain***, was designed and developed to support this experiment. The training material in this experiment was selected to target vowel letter dyslexia. It included the three essential short vowels (fat-ha "/a/", kasra "/i/",

dammah "/u/"), اَ ، اِ ، اُ and the three long vowels (alef "a", ya-a "i", waw "u"), أَ ، يِ ، وُ, starting from simple words (i.e. three-letter words containing only fat-ha short vowel and alef long vowel) and progressing to advanced ones (i.e. five-/six-letter words containing all three short vowels and the three long vowels) as shown in Table 5.1.

The experience of success in the system was a natural reward that is automatically calculated and controlled (Lyytinen et al., 2009). The learner must achieve 80% in each activity (Lyytinen et al., 2009; Al-Rubaian et al., 2014) to win and unlock the next activity. Otherwise, they repeat the activity. Repeating activities is beneficial for learners with dyslexia (Aljojo et al., 2018). Incorrect words were carefully selected to target vowel letter dyslexia difficulties: they were similar to the correct word in terms of letters and positions. They differed from the correct word in either deleting a long vowel (changing long to short vowel), adding a long vowel (changing short to long vowel) or changing the position of a long vowel. An example of this is shown in Figure 5.1.

Table 5.1: Training Material in Experiment 1

Activity	Content							
	Short Vowels			Long Vowels			#Letters within a word	
	Fat-ha	Kasrah	Dammah	Alef	Yaa	Waw	3-4	5-6
1	✓			✓			✓	
2	✓			✓				✓
3	✓	✓			✓		✓	
4	✓	✓			✓			✓
5	✓		✓			✓	✓	
6	✓		✓			✓		✓
7	✓	✓	✓	✓	✓	✓	✓	✓
8	✓	✓	✓	✓	✓	✓	✓	✓

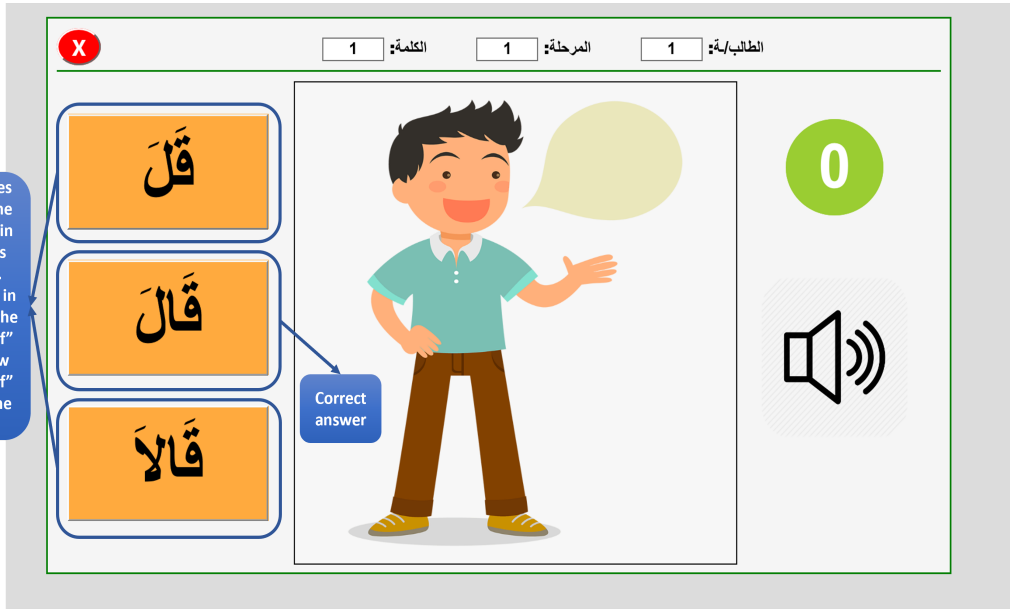


Figure 5.1: Example of Incorrect Choices in Experiment 1

5.2.1 Hypotheses

Two hypotheses were tested:

> **H1.1:** Matching training material to learners with vowel letter dyslexia achieves significantly greater learning gain compared to learners with short vowel dyslexia.
>
> **H1.2:** Matching training material to learners with vowel letter dyslexia achieves significantly greater learner satisfaction compared to learners with short vowel dyslexia.

5.2.2 Procedure

To understand the impact of matching the training material to vowel letter dyslexia, a controlled experiment was conducted. It was subject to ethical approval by the institution and explicit consent for each learner. A mixed-methods approach was used for data collection and analysis. Quantitative data were collected from (1) pre- and post-tests to derive learning gain scores and (2) learner satisfaction questionnaire to derive learner satisfaction scores. Qualitative data were collected from observations. The experiment took place in Riyadh, Kingdom of Saudi Arabia (KSA). It followed the procedure detailed in Section 4.7. The dyslexia diagnostic test used in this experiment determines only two Arabic dyslexia types; vowel letter dyslexia, short vowel dyslexia or other. The matched (experimental) group included learners with Arabic vowel letter dyslexia while the mismatched (control) group included learners with Arabic short vowel dyslexia. Both groups used the same e-learning system. The training material of the system matched the Arabic dyslexia type difficulties of the experimental group while it did not match the Arabic dyslexia type difficulties of the control group.

As mentioned in Chapter 4, the experiment was conducted both face-to-face and then online after COVID-19 led to the closure of all schools:

- ***Face-to-face Mode***: Conducting the experiment personally in schools.
- ***Online Mode***: Conducting the experiment remotely using Zoom meetings.

The online mode was challenging because a number of steps were required before starting the experiment:

- Getting the contact numbers of special education teachers to search for learners with Arabic dyslexia.
- Obtaining initial consent from parents via the teachers.
- Getting the contact numbers of the parents who agreed for their children to participate in the experiment.

- Describing the experiment to the parents via WhatsApp.
- Sending the consent forms to the parents via WhatsApp.
- Checking with the parents about the availability of either a laptop or a smartphone to be used for the experiment.
- Creating a schedule with the parents for conducting the sessions.
- Recording a video demonstrating the steps of installing Zoom Meetings and sending it to the parents.
- Following up with parents during Zoom installation and verifying that the installation is successful.
- Directing the parents to the use of both the microphone and the camera to run a video meeting and observe the learner during the experiment.
- Ensuring that the learner is by themselves in a quiet room to get their full attention and that they can use the system without any external assistance and distraction.
- Starting the experiment following the procedure explained earlier in Section 4.7.

5.2.3 Participants

The experiment targeted 20 learners with Arabic dyslexia by conducting it twice. The first run was conducted during the autumn term 2019/2020 while the second was conducted during the spring term 2019/2020. In each run, the experimenter was able to recruit no more than 10 learners due to practical reasons:

- A maximum of 20 sessions per week were used to conduct the experiment as shown in Table 5.2. As there were few participants who met the conditions of the experiment (learners with Arabic vowel letter dyslexia/short vowel dyslexia) in each school and the experimenter had to conduct the experiment herself to observe the learners, one by one, and to take notes in an equal manner, she had to go to other schools to recruit more participants and therefore some sessions were excluded (highlighted in grey).
- Each learner should attend two experimental sessions per week. Considering the previous point (20 sessions available per week), a maximum of 10 learners will be able to participate in the experiment in each run.

Twenty female learners, already diagnosed with Arabic dyslexia, were recruited from different Saudi primary schools located in Riyadh. The ages of the learners ranged from 9 to 12 years (Grades four to six) and one learner was 14 years old (see Figure 5.2). This learner was exceptional because she was in the sixth grade and not in high school, and according to the education policy, she could only

Table 5.2: Example for The Ideal Distribution of 20 Experimental Sessions in a School Schedule

Day-Session	1	2	3	4	5	6	7
Sunday		1	2		3	4	
Monday		5	6		7	8	
Tuesday		9	10		11	12	
Wednesday		13	14		15	16	
Thursday		17	18		19	20	

be transferred to the next higher grade if she had mastered certain skills. All learners have previous experience using electronic devices. Learners were assigned either to the mismatched group (n=12) or the matched group (n=8). Participants had approximately the same initial reading skill level (measured by the pre-test), with no statistically significant difference between the two groups. Thirteen out of 20 learners completed the experiment in school. Three other learners completed it remotely via Zoom Meetings due to the closure of schools (COVID-19). Zoom Meetings made it possible to open the camera and observe these learners while using the system. The remaining four learners did not complete the experiment, because:

- Learner's parents refused their participation remotely.
- Learner refused to participate in the experiment remotely, thinking that they were on holiday.
- Learner had poor Internet connection.
- Learner did not have a device to conduct the experiment remotely.

Therefore, the sample size dropped to 16 learners with eight learners in each condition.

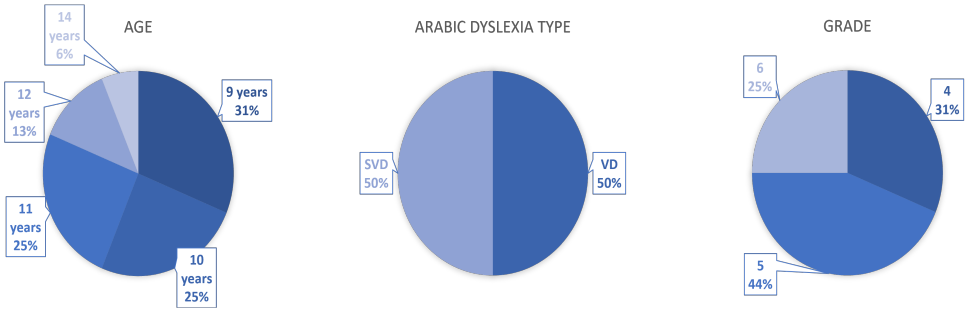


Figure 5.2: Demographic Information of Participants in Experiment 1

5.2.4 Results and Discussions

The groups of learners were homogeneous in terms of number of learners, initial reading level and age. The mean age of the matched group was 10.13 (Standard Deviation = 1.25) whereas for the mismatched group was 10.75 (Standard Deviation = 1.58). The learners were encouraged to take part in the experiment to improve their reading. Quantitative and qualitative results are detailed below.

5.2.4.1 Quantitative Results

The pre- and post-test and the learner satisfaction scores were collected to measure both the learning gain and learner satisfaction. Table 5.3 illustrates the mean and standard deviation of these data.

Table 5.3: Means and Standard Deviations (SD) of Pre- and Post-Test, Learning Gain (LG) and Learner Satisfaction (LS) Scores for Both Groups in Experiment 1

Group	N	Pre-test		Post-test		LG		LS	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Matched Group	8	2.13	1.73	5.75	1.75	3.63	1.41	4.75	0.71
Mismatched Group	8	1.75	2.05	5.75	2.25	4.00	2.00	4.50	1.41

Learning Gain. Hypothesis H1.1 was tested in this experiment. Figure 5.3 shows that the mean learning gain of both the matched and mismatched groups was positive (the mean of the post-test score was higher than the mean of the pre-test score). This indicates that the reading of both groups improved regardless of their Arabic dyslexia type. Whilst this suggests that the system and the training material were effective and the learner's learning was enhanced, it should be noted that the learners were also taking conventional lessons over the period of the experiment. We should, therefore, be cautious in drawing any conclusion. It also should be noted that Arabic societies speak different Arabic dialects. Some of these dialects are close to Modern Standard Arabic while others are far, which may affect the manifestation of Arabic dyslexia (AlRowais et al., 2013) and therefore the reading of the learners. Also, Modern Standard Arabic is the Arabic language version that was used in the system as the training material was chosen from the academic textbooks of Saudi primary school (which are written in Modern Standard Arabic).

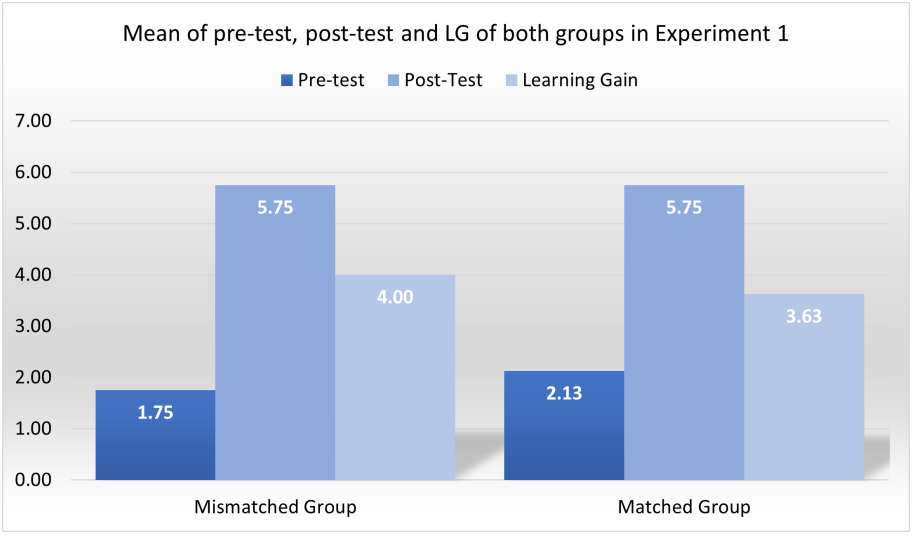


Figure 5.3: Means of Pre- and Post-Test and Learning Gain Scores of Both Groups in Experiment 1

The mean learning gain score of the mismatched group was higher than that of the matched group. We cannot, therefore, conclude that matching learning material to vowel letter dyslexia enhances learner's learning. Hypothesis H1.1 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 experiment with a larger number of learners would produce a different result. Alternatively, it may just be that the skill targeted (reading words with short and long vowels) was one that the control group (learners with short vowel dyslexia) had still not mastered. The assumption of the experimental design was that learners with short vowel dyslexia would not benefit significantly from learning targeted at learners with vowel letter dyslexia (since this is not a difficulty that they have). However, if this was a skill that these learners had yet to learn, then it may be that they would acquire this skill more quickly than those learners for whom it would represent a greater challenge. However, these findings contradict those of (Alghabban and Hendley, 2020a) and, therefore, more investigation is needed.

Learner Satisfaction. Learner satisfaction for both groups was measured by asking the participants for their opinions of the system (see Appendix E). The mean learner satisfaction score for the matched group (Mean = 4.75, Standard Deviation = 0.71) is approximately the same for the mismatched group (Mean = 4.50, Standard Deviation = 1.41). This indicates that both groups were highly satisfied with the system regardless of their Arabic dyslexia type. As the satisfaction scores for both groups were extremely high and there was, in effect, no opportunity to discriminate between the satisfaction of the two groups, it cannot be concluded that matching the training material to vowel letter dyslexia has an effect on the level of learner satisfaction. Therefore, H1.2 is rejected.

This is not the expected result. There are several reasons that could explain this:

- Convergence of learning gain scores for both groups of learners.
- Young age of learners might lead them to:
  - Be unaware of to what extent the content was appropriate.
  - Choose the extreme scores (Wilson and Conroy, 1999; Sim et al., 2006).
  - Focus more on the system interface rather than its content as both groups used the same system interface and facilities.

Finally, all learners regardless of their experimental group were highly satisfied with the system and therefore highly motivated, engaged (Kangas et al., 2017; Alghabban and Hendley, 2020b) and enjoyed using the system (Lin et al., 2017). This, perhaps explains why none of the learners dropped

voluntarily from the experiment once they had started using the system as high satisfaction leads to continue use of the system (Chou and Chen, 2009) and indicates the system's ease of use and usefulness (Lin et al., 2017). It is worth mentioning that the quantitative findings are true only for this sample of learners and cannot be generalised due to the small sample size, therefore more investigation is required.

5.2.4.2 Qualitative Results

The qualitative data were collected by the experimenter while observing each learner at each session as detailed in Section 4.7. The thematic map of the observations is illustrated in Figure 5.4.

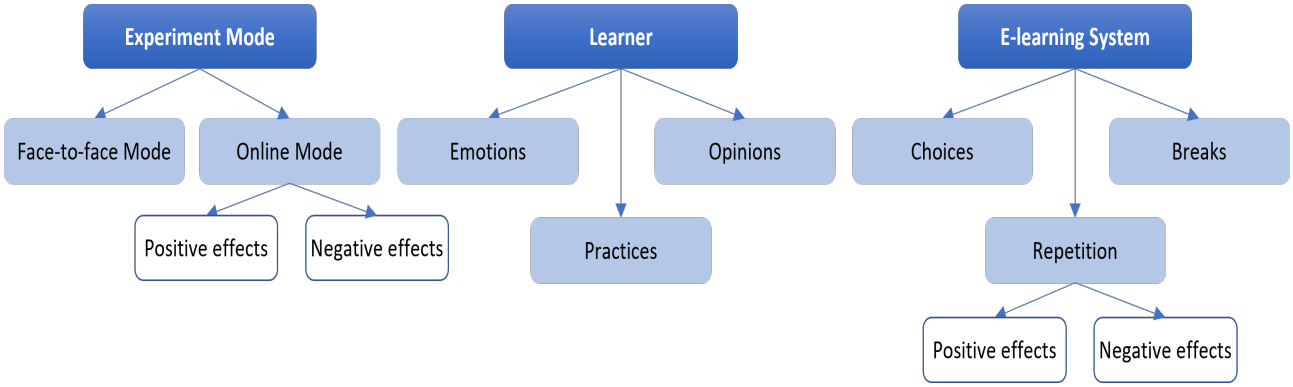


Figure 5.4: Thematic Map of Observations in Experiment 1

During observation of the learners while interacting with the system, several findings were noted in terms of experiment mode, learners and e-learning system. In terms of ***experiment mode***, 13 learners completed the experiment in person (face-to-face mode) while the remaining three completed the experiment remotely using Zoom Meetings (online mode). However, the online mode affected the experiment both positively and negatively. In terms of ***positive effects***, the learner used the system regardless of location and time. In terms of ***negative effects***, both the clarity of the system's audio and the ability to observe the learner's facial expressions were negatively affected. Some learners could not hear the system's audio clearly ("**The sound is not clear**", or **physically brought their ears close to the device**) and the experimenter had to re-pronounce the target word to proceed, as well as re-pronounce the positive/negative feedback. Observing the facial expressions of some learners was also difficult for the experimenter, as the video quality for these learners was poor which affected the observation process.

In terms of ***learners***, a majority of them in both groups were happy and engaged each time they started a new experimental session. They reported that the system was "**better than the textbook**" and cited different reasons such as "**because it has audio**", "**because it has audio and I can choose**", "**I liked it because there is a challenge to win and better than the textbook because it has audio**", "**because it let me know my mistakes**". The audio feature

was the dominant reason for their happiness and engagement towards the system. However, late sessions were negatively affected. For instance, a learner was tired and demotivated because the session was conducted towards the end of the school day. Another learner was not engaged because the session took place during a school play. Further, the learners followed some practices to help them figure out the correct answer as illustrated in Table 5.4.

Table 5.4: Learner Practices in Experiment 1

Practice	Matched Group N(%)	Mismatched Group N(%)
Listening carefully to target word's audio	8 (100%)	7 (87.5%)
Spelling out target word (decoding the word)	8 (100%)	7 (87.5%)
Removing the short vowel of the last letter	0 (0%)	1 (12.5%)
Using finger to spell out the target word on the table	1 (12.5%)	0 (0%)
Using the displayed image	1 (12.5%)	1 (12.5%)

One learner in the mismatched group had a lack of focus and therefore read randomly as her teacher mentioned during the interview.

In terms of the ***e-learning system***, a number of findings were revealed. Some of them had to do with the choices that are displayed to the learner to select from. Others had to do with the repetition feature provided by the system and the breaks that were taken by the learner during the session.

Choices:

- Five learners in each group insisted that their incorrect choices were correct.
- Three learners in the mismatched group and one in the matched group were able to notice their failure in advance when they made more than two mistakes in a certain activity before this activity ends. So, they completed the exercises by choosing quickly and randomly in order to start afresh.
- A learner in the mismatched group focused on the points awarded and became happy and motivated each time she gained a point for a correct choice (Dymora and Niemiec, 2019).
- A learner in the matched group faced difficulty in choosing the correct choice and complained, "**The choices are too similar**". This is true because these choices were carefully chosen to target the vowel letter dyslexia's symptoms as mentioned earlier in Section 5.2.

Repetition Feature: Repeating exercises is reported to be useful for learners with dyslexia (Aljojo et al., 2018) and enhances the learner's short-term memory (Alghabban et al., 2021). In this experiment, none of the learners in either group was able to complete all of the eight activities at

the first attempt. They repeated some of these activities many times until they succeeded. This repetition had positive and negative effects as shown in Table 5.5.

Further, more than half of both groups completed either six or seven reading activities within the eight experimental sessions. However, one learner in the matched group completed only half of the activities. This learner was exceptional as she had an additional problem that led her to lose focus and therefore choose wrong answers.

Table 5.5: Positive and Negative Effects of Repetition Feature on Both Groups in Experiment 1

Effect Type	Effect	Matched Group N(%)	Mismatched Group N(%)
Positive	Improved focus in later attempts	3 (37%)	3 (37%)
	Recalling mistakes and thus avoid repeating them	1 (12%)	0 (0%)
	Memorising correct choices leading to re-choosing them quickly without re-listening to the target word	5 (62%)	3 (37%)
Negative	Boredom which led to losing focus and thus choosing their answers randomly-perhaps to either waste time or to win by chance	5 (62%)	4 (50%)
	Unable to complete all eight training activities during the eight experimental sessions	5 (62%)	5 (62%)

The choices of each activity are re-ordered each time the learner restarts that activity. This ensures that the learners did not memorise the position of the correct answers. Instead, they had to re-read the choices to figure out the new position of the correct choice. However, a learner in the mismatched group fell into the trap of memorising the position of the correct choice rather than re-searching for that choice.

Breaks: A learner in the mismatched group reported "**it is hard and I prefer to use paper**". This is, perhaps, because the paper does not force her to repeat until she succeeds, as in the system. So, she took breaks during the sessions and was agitated. She was different from others by moving a lot and being unstable during the session and thus losing her focus. Another learner in the matched group took a break during one of the sessions. It might be that she was tired because she had a math session before conducting the experimental session.

To sum up, the observations revealed that the system affected learners differently regardless of their enrolled group:

- The majority of learners were happy and engaged with the system due to its interactivity feature. It enabled them to choose and provided them with visual and verbal feedback.

- Learners followed different practices to identify the correct answer. The majority of them, for instance, listened carefully to the audio of the target word while others spelt it out to decode it.
- The majority of learners insisted on their incorrect choices being correct because they could not figure out the problem with their choices.
- The repetition feature had two side effects. It either made the learners more focused when solving the activity for success or it made them bored with repetition of the activity.

5.2.5 Lessons Learnt

During this experiment, several lessons were learned. Some were related to the participants while others were related to the e-learning system.

Participants:

- Few participants were found to have either vowel letter dyslexia or short vowel dyslexia in each school because the experiment only targeted learners in high-level grades (4th, 5th, and 6th grades). These levels were chosen because the training material included five-/six-letter words that are more suitable for them than learners in lower levels. Thus, to increase the number of participants, learners in low-level grades (2nd and 3rd grades) should also be included. This will influence the training material of the system by including appropriate words for these lower-level learners.
- Not all learners enrolled in the learning difficulty program within the school have a learning difficulty. Some of them lack diligence while others have language problems. Therefore, before recruiting a learner from this program, we must verify that this learner is indeed having dyslexia.
- Similar verbal and non-verbal expressions were recorded among the participants as they interacted with the system. Therefore, designing a checklist that includes these expressions would simplify the observational process.

E-learning System:

- Repeating the same activity with the learner until they succeed was a good practice. It forced the learner to focus more on the word they had heard in order to choose the correct answer. Unfortunately, some learners repeated the activity several times until they got bored. In this case, the number of repetitions should be limited or another way of re-presenting the activity should be considered.

- Some learners repeated their incorrect choices over and over again, insisting that this is the correct answer. Therefore, using verbal feedback that pronounces any incorrect answer will enable the learner to listen to the correct pronunciation of their incorrect choices. This might avoid them from re-choosing these incorrect choices and improve their reading.
- Re-ordering the choices, once the activity was restarted, was a good practice. This prevented the learner from memorising the position of the correct choice and thus choosing the position instead of the choice.
- The choices in each question were similar to the correct choice in terms of the letter identity and positions. This approach forced the learner to think carefully, try to figure out the correct answer and help them to distinguish between the sounds of short and long vowels.
- The learner could not move to the next activity until they reached the threshold score (80%). Further, they were forced to solve all the exercises in a given activity even if they knew in advance that they would not reach this threshold score and would therefore restart the activity. However, forcing learners to complete the activity, with prior knowledge of failure, was not a good practice. Some learners preferred to randomly answer the remaining exercises in order to restart the activity afresh. Thus, another situation should be considered.
- Since the system is aimed at children, its voice has been modified to mimic a child's voice. Unfortunately, the intelligibility of the sound was negatively affected, which in turn negatively affected the sound's clarity for some of the letters within the word. So, using the original adult voice will be better.
- Using five- and six-letter words in some activities was a challenge for learners with dyslexia. Therefore, using shorter words would be appropriate, because the main goal of the experiment is to train learners to distinguish between the sounds of short and long vowels and not force them to fail which may cause them to become depressed and lower their self-esteem.

5.3 Conclusion

This chapter introduced the first experiment of this research. It investigated the impact of matching training material to Arabic vowel letter dyslexia on learner's reading performance, satisfaction and behaviour. A mixed-methods approach of qualitative and quantitative data was used. The experiment was conducted with 16 learners with Arabic vowel letter dyslexia and short vowel dyslexia. Quantitative findings showed a positive effect on learners' learning gain and a high level of learner satisfaction regardless of their Arabic dyslexia type. Overall, learners in both conditions seem to learn according to their significant positive scores in learning gain and learner satisfaction.

However, we did not find any statistically significant difference in either metric in either condition. Qualitative findings showed that the majority of learners were happy and engaged during their interaction with the system. In addition, learners followed some good practices to find out the correct answer such as listening carefully to the target word and spelling it out. However, many learners insisted on the correctness of their errorful answers and it might be beneficial to add auditory feedback to remedy this. It was also clear that many learners had additional problems that affected their ability to perform the experiment. The question is: what if short vowel dyslexia was targeted instead of vowel letter dyslexia? This is what the next experiment will focus on, taking into account the lessons learned from this experiment, which will lead to update the training material and change some functions of the system. Details are provided in the next chapter.

Chapter 6

Matching Training Material to Learners with Arabic Short Vowel Dyslexia

6.1 Introduction

Chapter 5 introduced the first experiment of this research that aimed to understand the impact of matching training material to learners with Arabic vowel letter dyslexia on their reading performance, satisfaction and behaviour. A complementary experiment, "Experiment Two", was designed and conducted. Similarly to "Experiment One", it targeted vowel letter dyslexia and short vowel dyslexia. However, it studied the impact of matching training material to short vowel dyslexia (instead of vowel letter dyslexia as in Experiment One) on the learner's learning. This chapter will introduce this experiment and its results.

6.2 Experiment Two

Experiment Two was conducted as a pilot in order to (1) understand the impact of matching the training material to learners with short vowel dyslexia (instead of vowel letter dyslexia) on their reading performance, satisfaction and behaviour and (2) validate the updated version of the system and tools used in this experiment. The training material of the ***DysTypeTrain*** system used in Experiment One was modified to fit the aim of this experiment. It was chosen to target short vowel dyslexia instead of vowel letter dyslexia by combining only the three essential short vowels (fat-ha "/a/", kasra "/i/", dammah "/u/"), بَ ، بِ ، بُ in a word. It progresses from simple words (i.e. three-letter words with only fat-ha short vowel) to advanced ones (i.e. four-letter words with a mix of all the three short vowels) as illustrated in Table 6.1. Incorrect options were carefully selected to target short vowel dyslexia difficulties. This was achieved by choosing words similar to the correct

answer in terms of letters and positions and differing only in the short vowels (diacritical marks) of each letter. An example of this is shown in Figure 6.1.

Table 6.1: Training Material in Experiment 2

Activity	Content				
	Short Vowels			#Letters within a word	
	Fat-ha	Kasrah	Dammah	3	4
1	✓			✓	
2	✓			✓	✓
3	✓	✓		✓	
4	✓	✓		✓	✓
5	✓		✓	✓	
6	✓		✓	✓	✓
7	✓	✓	✓	✓	✓
8	✓	✓	✓	✓	✓

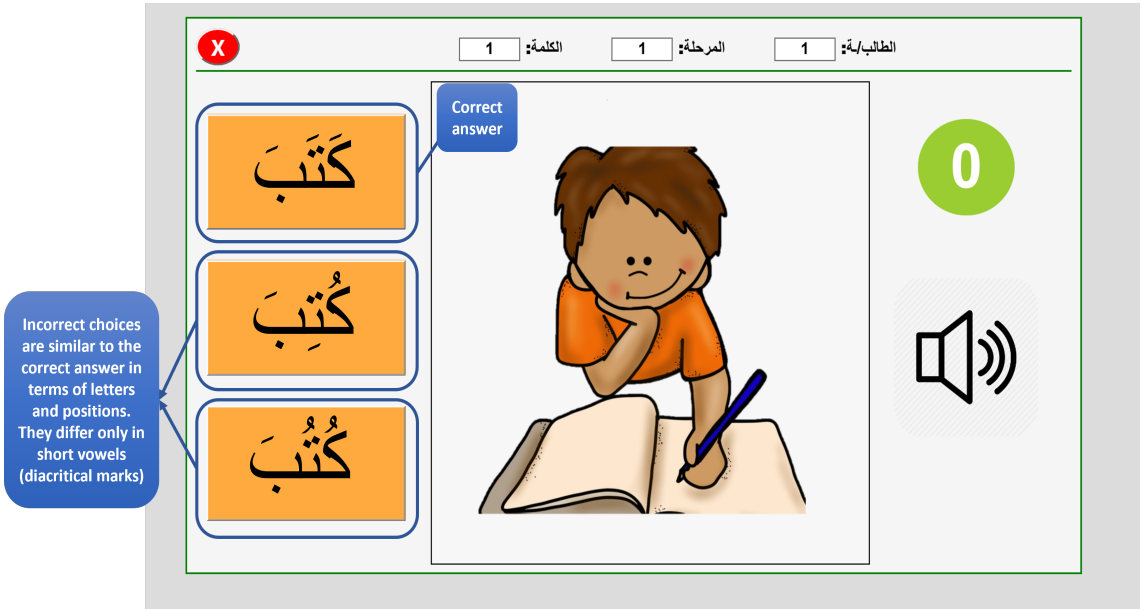


Figure 6.1: Example of Incorrect Choices in Experiment 2

Based on the lessons learned from Experiment One, the following updates were applied to this experiment:

- The learner's incorrect choice is read aloud by the system to (1) provide them with the correct pronunciation of their incorrect choice and (2) prevent them from insisting on their mistakes being correct.
- The repetition feature is modified. After a learner has three goes, one of the incorrect choices will be removed so that they will have only two choices.
- The recorded audios are kept in their original (adult) voice to maintain their clarity.
- The learners recruited for this experiment are in grades from two to six.

- The training material in Experiment One was difficult for learners with dyslexia, especially the five- and six-letter words. Therefore, in this experiment, the training material was restricted to three- and four-letter words.
- To simplify the observation process, two checklists were designed based on Experiment One's qualitative results; observed fun and observed usability checklists (see Appendices G and H).

6.2.1 Hypotheses

Two hypotheses were tested:

> **H2.1:** Matching training material to learners with short vowel dyslexia achieves significantly greater learning gain compared to learners with vowel letter dyslexia.

> **H2.2:** Matching training material to learners with short vowel dyslexia achieves significantly greater learner satisfaction compared to learners with vowel letter dyslexia.

6.2.2 Procedure

This experiment followed the same procedure as Experiment One as described in Section 5.2.2. This experiment targets short vowel dyslexia and thus the matched (experimental) group includes learners with Arabic short vowel dyslexia while the mismatched (control) group includes learners with Arabic vowel letter dyslexia. Additionally, during the observation process, learner's fun and usability of the system were observed and the corresponding checklists were filled in. These were observed to determine whether the learners were motivated as they interacted with the system and to capture what worked and what did not work in the system. Other issues were also recorded. More details are available in Section 6.2.4.2.

6.2.3 Participants

Twenty-three female learners, already diagnosed with Arabic dyslexia, were recruited from different primary schools in Riyadh, Kingdom of Saudi Arabia (KSA). The age of the learners was from 7 to 11 years (Grades two, three, four and six) (see Figure 6.2). All learners have previous experience using electronic devices. Learners were assigned to either the mismatched group (n = 10) or the matched group (n = 13). There was no statistically significant difference in the initial reading skill level (measured by the pre-test) between the two groups. Fourteen out of 23 learners completed the experiment in school. Eight other learners completed it remotely via Zoom Meetings due to school closures (COVID-19). The remaining learner did not complete the experiment because the experimenter could not reach their contact number to conduct the experiment remotely. Therefore, the sample size dropped to 22 learners who completed the experiment with nine learners in the mismatched group and 13 in the matched group.

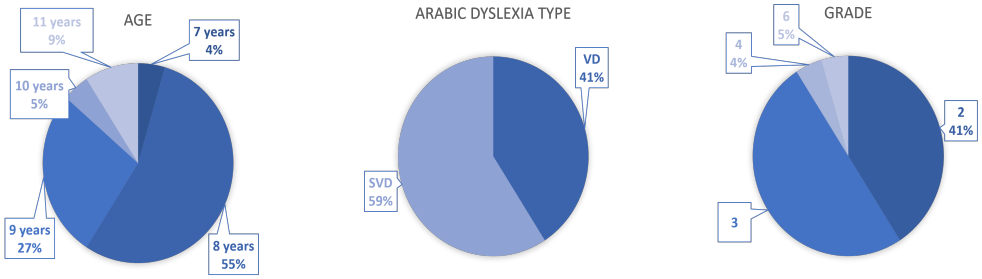


Figure 6.2: Demographic Information of Participants in Experiment 2

6.2.4 Results and Discussions

The groups of learners were homogeneous in terms of initial reading level and age. The learners were in the second, third, fourth and sixth grades. The mean age of the matched group was 8.69 (Standard Deviation = 1.18) whereas for the mismatched group it was 8.44 (Standard Deviation = 0.73). The learners were encouraged to take part in the experiment to improve their reading. Quantitative and qualitative results are detailed below.

6.2.4.1 Quantitative Results

The pre- and post-test and the learner satisfaction scores were collected to measure both the learning gain and learner satisfaction. Table 6.2 illustrates the mean and standard deviation of these data.

Table 6.2: Means and Standard Deviations (SD) of Pre- and Post-Test, Learning Gain (LG) and Learner Satisfaction (LS) Scores for Both Groups in Experiment 2

Group	N	Pre-test		Post-test		LG		LS	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Matched Group	13	3.38	1.76	7.54	2.57	4.15	2.38	4.92	0.28
Mismatched Group	9	2.89	2.52	8.44	1.81	5.56	1.74	5.00	0.00

Learning Gain. Hypothesis H2.1 was tested in this experiment. Similarly to the results of Experiment One, Figure 6.3 shows that the mean learning gain of both the matched and mismatched groups was positive. Again, this:

- Indicates that the reading of both groups improved regardless of their Arabic dyslexia type.
- Suggests that the system and the training material were effective and the learner's learning was enhanced.

However, it should be noted that the learners were also taking conventional lessons over the period of the experiment, therefore we should be cautious in drawing any conclusion. It also should be noted that Arabic societies speak different Arabic dialects. Some of these dialects are close to Modern Standard Arabic while others are far, which may affect the manifestation of Arabic dyslexia

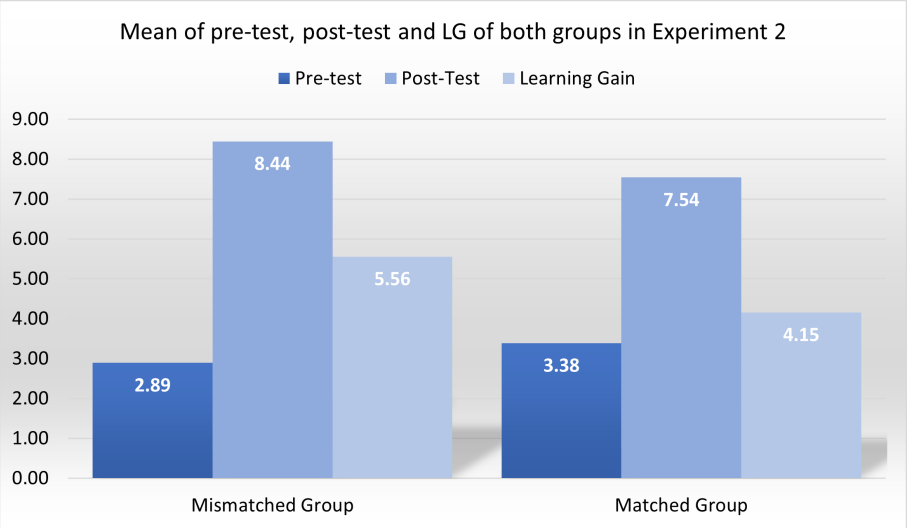


Figure 6.3: Means of Pre- and Post-Test and Learning Gain Scores of Both Groups in Experiment 2

(AlRowais et al., 2013) and therefore the reading of the learners. Also, Modern Standard Arabic is the Arabic language version that was used in the system as the training material was chosen from the academic textbooks of Saudi primary school (which are written in Modern Standard Arabic). The mean learning gain score of the mismatched group was higher than that of the matched group. We cannot, therefore, conclude that matching learning material to short vowel dyslexia enhances the learner's learning. Hypothesis H2.1 is, therefore, rejected. Like Experiment One, this is not the expected result. It may be that this is just a consequence of the small number of experimental subjects and that repeating the experiment with a larger number of learners would produce a different result. Alternatively, the control group (learners with vowel letter dyslexia) did not have a problem with the skill targeted in this experiment (reading words with only short vowels), because they have a problem with another higher-level skill. The assumption of the experimental design was that learners with vowel letter dyslexia would not benefit significantly from learning targeted at learners with short vowel dyslexia (since this is not a difficulty for them). So, the learners in the control group would acquire this skill more quickly than those learners for whom it would represent a greater challenge. Similarly to Experiment One, these findings contradict those of (Alghabban and Hendley, 2020a). This may be due to several reasons which are detailed in Section 6.3.

Learner Satisfaction. Learner satisfaction was measured for both groups by asking the participants for their opinions of the system (see Appendix E). Like Experiment One, the mean learner satisfaction score for the matched group (Mean = 4.92, Standard Deviation = 0.28) is approximately the same for the mismatched group (Mean = 5.00, Standard Deviation = 0.00). This indicates that both groups were highly satisfied with the system regardless of their Arabic dyslexia type. As the satisfaction scores for both groups were extremely high and there was, in effect, no

opportunity to discriminate between the satisfaction of the two groups, it cannot be concluded that matching the training material to short vowel dyslexia has an effect on the level of learner satisfaction. Therefore, H2.2 is rejected.

This is not the expected result. There are several reasons that could explain this:

- Convergence of learning gain scores for both groups of learners.
- Young age of learners might lead them to:
  - Be unaware of to what extent the content was appropriate.
  - Choose the extreme scores (Wilson and Conroy, 1999; Sim et al., 2006).
  - Focus more on the system interface rather than its content as both groups used the same system interface and facilities.

Similarly to Experiment One, all learners regardless of their experimental group were highly satisfied with the system and therefore highly motivated, engaged (Kangas et al., 2017; Alghabban and Hendley, 2020b) and enjoyed using the system (Lin et al., 2017). This, might explain why none of the learners dropped voluntarily from the experiment once they have started using the system as high satisfaction leads to continue using the system (Chou and Chen, 2009) and indicates the system's ease of use and usefulness (Lin et al., 2017). Again, the quantitative findings are true only for this sample of learners and cannot be generalised due to the small sample size.

6.2.4.2 Qualitative Results

The qualitative data were collected by the experimenter while observing each learner at each session. The thematic map of the observations is illustrated in Figure 6.4.

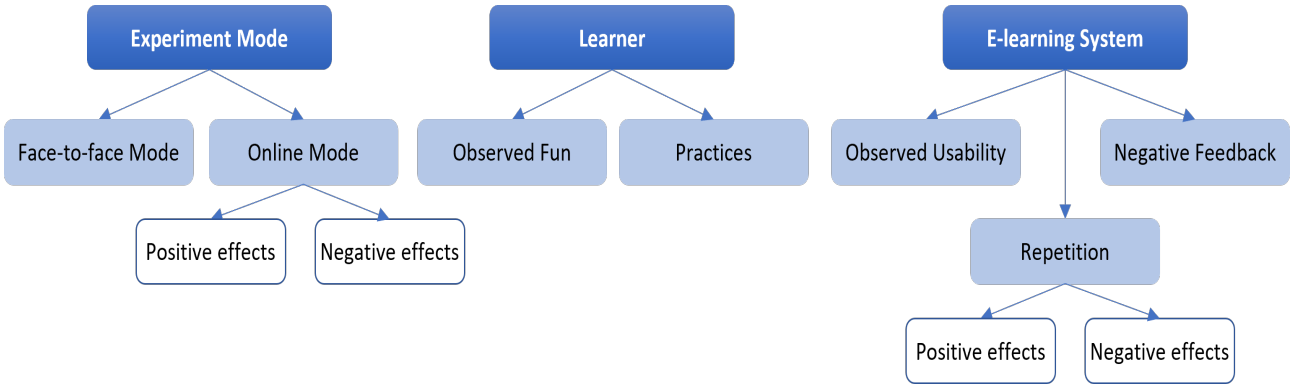


Figure 6.4: Thematic Map of Observations in Experiment 2

Again, the observations were categorised into experiment mode, learners and e-learning system. In terms of ***experiment mode***, six learners of the mismatched group and eight learners of the matched group completed all their eight experimental sessions in person (face-to-face mode). Whereas, three learners of the mismatched group completed only the first two sessions in person while the

remaining sessions were completed remotely via Zoom Meetings (online mode) and five learners of the matched group completed all of their eight experimental sessions remotely. However, conducting the experiment remotely had positive and negative effects. In terms of ***positive effects***, the learner can conduct the experiment from anywhere, at any time without being restricted to school day and classes. In terms of ***negative effects***, the online mode affected the:

- *Ability to observe the learner's facial expressions:* The facial expressions of some learners was difficult for the experimenter to observe, because the quality of video calling for these learners was poor and thus affected the observation process.
- *Clarity of the system's audio:* The system's audio was not clear to some learners ("**I cannot hear the sound**", so the experimenter had to repeat it (whether the target word or the positive/negative feedback).
- *Clarity of the system choices:* The size of the short vowels in the choices was too small ("**The choices are all the same**") so the experimenter had to enlarge the screen to make them clearer. Probably because the learners were using smartphones instead of a laptop.

In terms of ***learners***, their fun was observed and a checklist was filled during the first experimental session. Table 6.3 illustrates that the majority of learners in both groups were happy and engaged ("**The game is nice**"). This is might be due to these reasons:

- The system used a training strategy different from that of their teachers (either in the classroom or in their personal sessions) and therefore this strategy captured the learner's interest.
- The interactive feature of the system- such as feedback, on-demand audio playback of the target word and displaying the overall progress- is missing from the textbooks and thus also captured the learner's interest.

Table 6.3: Observed Fun Results of Experiment 2

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

Furthermore, the learners followed some practices to help them figure out the correct answer as illustrated in Table 6.4.

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 from the system.

Table 6.4: Learners Practices in Experiment 2

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

Observed Usability. The usability of the system was determined by observing the learner's interaction with the system and the checklist was filled out during the first experimental session without helping the learner in using the system (Ismail et al., 2011). Table 6.5 shows that the image, text and buttons were clear for all learners in both groups whereas audio was not clear for some of them because they conducted the experiment remotely, as mentioned earlier. Additionally, the majority of learners understood the buttons' roles and system feedback and did not have to return to the previous page to correct their actions. However, the experimental instructions 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 6.5. So, later on, the instructions were further clarified to help learners to proceed with the experiment.

Table 6.5: Observed Usability Results of Experiment 2

Usability Issue	Matched Group N(%)	Mismatched Group N(%)
Is sound clear?	8(62%)	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(88%)

Repetition Feature. All learners of the mismatched group and 12 learners of the matched group completed all of the eight reading activities within the eight experimental sessions. The remaining learner of the matched group completed only seven instead of eight as one activity spanned over two sessions. This learner has various problems such as slow reading, severe reading difficulty (difficulties with letter recognition and inability to blend the phoneme of letters to form a word), choosing quickly and randomly and problems with concentration. While working with these activities, the learner either completed the activity on the first attempt or repeated it several times

until successful. Repeating the activity positively affected four learners of the mismatched group and two of the matched group by increasing their focus on the target word.

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 to the next exercise. In the matched group, only one learner did that. This learner had difficulties such as hyperactivity and problems in concentration.

Generally, the observations exposed that:

- Both face-to-face and online modes have pros and cons in terms of observation, system audio and experiment time and location.
- The majority of learners in both groups were happy and engaged with the system.
- Different practices were followed by the learners to figure out the correct answer such as re-playing the target word to identify its phonemes.
- The system was usable and understandable.
- The repetition feature increased the learner's focus to choose correctly.
- A minority of learners did not like their mistakes to be highlighted and skipped to the next exercise.

6.3 Experiments One and Two Discussion

Experiments One and Two are complementary. Both (1) targeted learners with Arabic vowel letter dyslexia and short vowel dyslexia in Riyadh primary schools, (2) used the matched/mismatched experimental design, (3) collected quantitative and qualitative data, (4) followed the same procedure, (5) measured the learning gain, learner satisfaction and behaviour and (6) validated the system and the tools. The results of these experiments were similar and there was no statistically significant difference in learning gain and learner satisfaction between the control and experimental groups. However, these results are in conflict with the results of (Alghabban and Hendley, 2020a,b) which also targeted Arabic dyslexia types and measured the same quantitative measurements. This may be due to the differences between them as shown in Table 6.6.

Therefore, these issues should be considered in the third experiment:

- **Experiment Location:** Due to the COVID-19 pandemic, all schools in KSA were closed and the teaching was conducted online. So, the third experiment must be conducted remotely with learners regardless of their location in KSA.
- **Number of Participants:** Regarding the previous point, the experiment can be conducted at any time during the day outside the school schedule. In other words, we do not have

Table 6.6: Comparison Between Our Experiments and (Alghabban and Hendley, 2020a,b) Experiment

Issue	Our Experiments	(Alghabban and Hendley, 2020a,b) Experiments	Discussion
Experiment Location	Riyadh, KSA	Jeddah, KSA	Location could affect the experiment results as dyslexia is sensitive to language and dialects. Riyadh and Jeddah are the biggest cities in KSA with extreme differences in dialects.
Number of Participants	16 and 22	44	The more participants recruited, the more significant results can be found.
Experimental Design	Matched/ Mismatched	Adaptive/ Non-adaptive	Experimental design could also affect the experiment results.
Repetition Feature	Available	NA	Repeating exercises enhances learning. Therefore, repetition enhanced the learning of both groups in a similar way and did not yield significant results.
Arabic Dyslexia Type	Vowel Letter Dyslexia and Short Vowel Dyslexia	Letter Position Dyslexia and Vowel Letter Dyslexia	Our experiments targeted vowel letter dyslexia which is common in practice and is known as an Arabic dyslexia type in the literature (Friedmann and Haddad-Hanna, 2014) while short vowel dyslexia is not known as an Arabic dyslexia type. Unlike the experiments of (Alghabban and Hendley, 2020a,b) which targeted letter position dyslexia and vowel letter dyslexia, Arabic dyslexia types known in the literature, and also common in practice.

to be restricted to the school day anymore. This provides more sessions during the day for the experiment to be conducted in and therefore, more learners can participate in the third experiment.

- **Experimental Design:** The previous experiments were designed using the matched/ mismatched approach in which only one Arabic dyslexia type was targeted in the training material in each experiment. That is why the second experiment complemented the first by targeting the other Arabic dyslexia type in the training material. So, the third experiment will be designed using an adaptive/non-adaptive approach to target two Arabic dyslexia types in the training material at the same time without the need to conduct another complementary experiment.
- **Repetition Feature:** Repetition of exercises enhances the learner's learning. This means that once the exercises were repeated in the previous experiments, the learning gain scores for both groups improved similarly which may have resulted in no significant difference being

found between the two groups. So, this feature will be removed in the third experiment.

- **Dyslexia Type:** Dyslexia reading difficulties (Arabic dyslexia types) reported in the literature (Friedmann and Haddad-Hanna, 2014) did not exactly match the practice and vice versa. Letter position dyslexia was reported as common in the literature while not found in practice and short vowel dyslexia was found to be common in practice but not reported in the literature. Therefore, we need to understand dyslexia difficulties in practice from the perspective of experts to find the common Arabic dyslexia type to replace short vowel dyslexia. Once we find it, the third experiment will target it along with vowel letter dyslexia.

6.4 Conclusion

This chapter introduced the second experiment of this research. It is complementary to Experiment One presented in Chapter 5. It investigated the impact of matching training material to Arabic short vowel dyslexia on learner's reading performance, satisfaction and behaviour. A mixed-methods approach of qualitative and quantitative data was used. The experiment was conducted with 22 Arabic learners with vowel letter dyslexia and short vowel dyslexia. Similarly to Experiment One, the quantitative findings showed a positive effect on learners' learning gain and a high level of learner satisfaction regardless of their Arabic dyslexia type. Qualitative findings showed that the majority of learners were happy and engaged during their interaction with the system. In addition, learners followed good practices to figure out the correct answer such as decoding the target word and re-listening to it. Also, it was clear that one learner had additional problems that affected their ability to complete all sessions. From the results of Experiments One and Two, it appears that the learners in both conditions learn according to their significant positive scores in learning gain and learner satisfaction which are in line with the findings of (Alghabban and Hendley, 2020a,b). However, we did not find any statistically significant difference in either metric in either condition and therefore contradicts the findings of (Alghabban and Hendley, 2020a,b).
Various issues could explain this situation; the experiment location, number of participants, experimental design, repetition feature and Arabic dyslexia type. So, the third experiment will consider these issues by (1) conducting the experiment remotely to eliminate location restrictions, (2) increasing the number of participants, (3) using an adaptive/non-adaptive experimental design approach, (4) removing the repetition feature and (5) understanding dyslexia reading difficulties in practice from the experts' (special education teachers) perspective and combining it with literature (Friedmann and Haddad-Hanna, 2014) to find an Arabic dyslexia type common in practice. To implement the last issue, an exploratory questionnaire was designed and published among special education teachers. More details are available in the next chapter.

Chapter 7

Understanding Dyslexia From Teachers' Perspective

7.1 Introduction

Chapters 5 and 6 presented the first two experiments of this research, respectively. They targeted learners with Arabic short vowel dyslexia and vowel letter dyslexia. The results of these experiments were not statistically significant. These experiments were built on our understanding of learners with Arabic dyslexia from literature which unfortunately did not match practice, as was the case with letter position dyslexia (Friedmann and Haddad-Hanna, 2014). Likewise, what we found in practice did not actually match the literature, as was the case with short vowel dyslexia. So, in addition to our understanding of the literature, we need to build an understanding of the difficulties that frequently occur among learners with Arabic dyslexia in practice from the perspective of special education teachers and find another common Arabic dyslexia type. This will lead to combining literature and practice which in turn will refine our approach in the last experiment. Therefore, a questionnaire was designed and published to special education teachers, who are experts in the field, to build this practical understanding from their point of view and on the basis of their experience. This chapter presents the objectives of the questionnaire, its design, the methodology followed and discussion of the results.

7.2 Design

To design an effective questionnaire, we must (see Figure 7.1):

- Determine the objectives of the questionnaire.
- Specify the respondents.
- Formulate the questions.

- Order these questions.
- Pilot the questionnaire.
- Refine and produce the final version of the questionnaire.

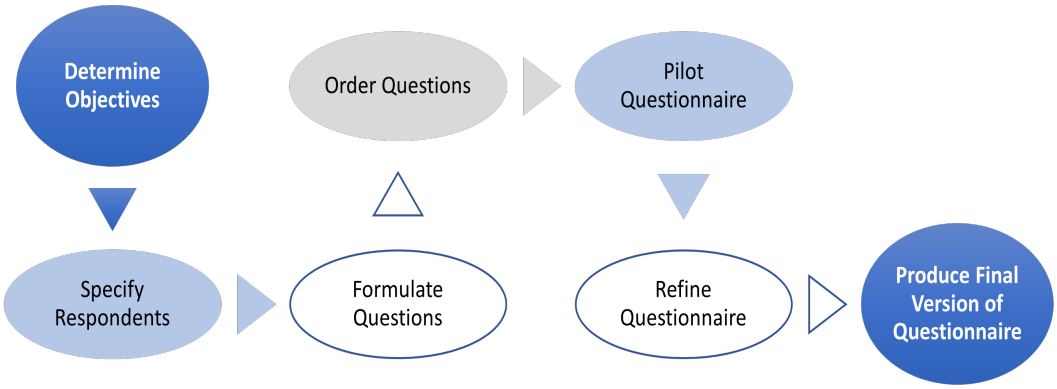


Figure 7.1: Design Steps of Questionnaire

7.2.1 Objectives

This questionnaire aimed to understand the difficulties faced by learners with Arabic dyslexia in Saudi schools (in practice) from the perspective of special education teachers through:

- Discovering the common reading and non-reading difficulties among learners with Arabic dyslexia.
- Determining the common Arabic dyslexia types (Friedmann and Haddad-Hanna, 2014) among learners with Arabic dyslexia in Saudi schools.
- Searching for justifications for the frequency of letter position dyslexia in Jeddah city and their infrequency in Riyadh city.
- Finding evidence for the prevalence of vowel letter dyslexia and short vowel dyslexia among learners with Arabic dyslexia in Saudi schools.
- Identifying teaching strategies that worked well with learners with Arabic dyslexia.
- Determining the technical features that special education teachers suggest to include or avoid in the design of the interactive educational tool.

7.2.2 Respondents

The best respondents to this questionnaire to achieve its objectives are special education teachers. They teach learners with Arabic dyslexia in individual sessions in which they give the learner their full attention. So, they are able to determine the difficulties of the learners from which Arabic dyslexia types can be identified. Also, these teachers are able to identify the teaching strategies that have worked well with these learners.

7.2.3 Questions Formulation

While formulating the questions; we have taken into account the objectives of the questionnaire, the simplicity of the questions, the type of question and the first language of the respondents.

In terms of *questionnaire objectives*, the questions are formulated to achieve them. There are questions about the reading problems and non-reading problems that learners with Arabic dyslexia may encounter in practice. Questions about reading problems were actually descriptions of Arabic dyslexia types. Keywords for Arabic dyslexia types were not used because they are often used by researchers and are not used or known by teachers who are the respondents to the questionnaire. This is to make the question wording familiar to these respondents. Questions about teaching strategies that worked well with these learners were also included. Some teaching strategies require the use of technology, so questions about the technical features that can be included/avoided in the design of interactive educational tool have been included.

In terms of *question simplicity*, one question was asked at a time to make it brief. For instance, "**Please list three common reading difficulties you have encountered among learners with dyslexia.**". Negative expressions have also been avoided to simplify the question.

In terms of *question type*, questions can be either open-ended or closed. In open-ended questions, the respondents can answer freely using their own words, such as "**Why do you think these are the most common reading difficulties from your perspective?**". In closed questions, pre-coded answers must be prepared from which the respondents can choose, such as "**During your teaching journey, have you ever encountered any students with dyslexia? (Yes, No)**".

Finally, the questionnaire was written in Arabic because it is the first language of special education teachers.

The questionnaire was designed with 40 questions which were divided into three sections: the demographic section (with nine questions), the dyslexia section (with 22 questions) and interactive educational tool section (with nine questions). The demographic section collected demographic information about the special education teachers such as academic level, gender and years of teaching experience. The data collected from this section can be used to analyse the data using different criteria such as gender and city. The dyslexia section explored the common dyslexia reading and non-reading difficulties of learners with Arabic dyslexia in the Kingdom of Saudi Arabia (KSA), the teachers' explanation for their frequency and the teaching strategies that improved their reading from the special education teachers' perspective. The interactive educational tool section discovered the features that special education teachers suggest adding and avoiding in the design of the interactive educational tool, the justifications for their suggestions and the teaching strategies that

they propose to include in the design of such a tool.

7.2.4 Questions Ordering

The questionnaire was ordered starting with the demographic section as it checks whether the respondent is a special education teacher. If not, they will be excluded and the questionnaire will be terminated. The dyslexia section, rather than the interactive educational tool section, was chosen as the second section for these reasons; (1) it contains another filtering question that only accepts the special education teachers with experience in teaching learners with Arabic dyslexia while others are excluded and (2) it contains questions that begin with an understanding of the difficulties faced by learners with Arabic dyslexia and end with questions about different teaching practices that have been used and worked well for them.

7.2.5 Questionnaire Piloting

After preparing the questionnaire, it was piloted (pre-tested) with a small number of Saudi special education teachers. This was to validate the questions and options, make sure they are clear and understandable and to increase the accuracy of responses. If not, the questions and/or options are modified. To do so, both criticisms and responses from special education teachers were collected. Teachers were asked (1) to read the questions to criticise them and (2) to answer the questionnaire as respondents which then were analysed to pick up any misunderstood questions.

Respondents

Eleven Saudi special education teachers (eight females and three males) participated in the pilot phase. Figure 7.2 illustrates their demographic information.

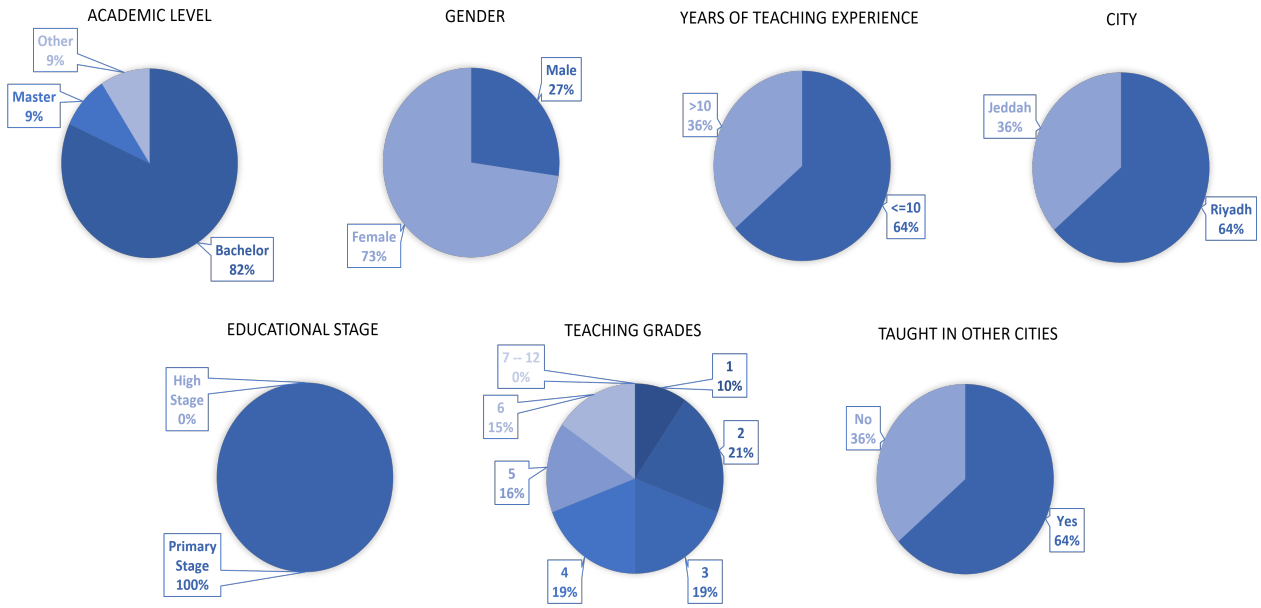


Figure 7.2: Demographic Information of Special Education Teachers in The Pilot Phase

Method

To pilot the questionnaire, the next steps were followed (see Figure 7.3):

1. Take a consent from the 11 special education teachers to participate in the pilot phase.
2. Send the questionnaire in the form of a MS Forms link to them via WhatsApp.
3. Collect their data (in the form of responses).
4. Take general comments about the questionnaire from each special education teacher along with detailed comments on each question.
5. Review the comments and the data collected from the questionnaire.
6. Revise the questions and the options of the closed questions based on the results of Step 5.
7. Produce the final version of the questionnaire.

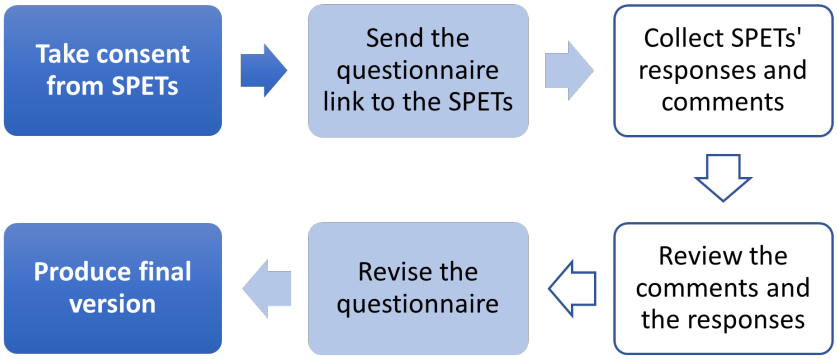


Figure 7.3: Framework of Pilot Phase

Results

The results of the pilot phase are categorised into: questionnaire length, general comments, detailed comments and special education teachers' responses and overall results.

Questionnaire length: The special education teachers were asked about the appropriateness of the questionnaire length. 40% of them claimed that the questionnaire was long while 60% claimed that the length was appropriate.

General comments: General comments were taken from the special education teachers about the questionnaire. The positive comments are that the questionnaire was (1) very detailed, (2) ("**perfect and complete**"), (3) clear ("**I was able to answer the questions**"), (4) appropriate for everyone, (5) ("**good and the sections are excellent**") and (6) reflected what is in the field. The negative comments along with our comments are illustrated in Table 7.1.

Detailed comments and special education teachers' responses: Comments on each question were taken from special education teachers and their responses were analysed to capture the unclear and misunderstood questions and/or options. This resulted in the following updates:

- **Demographic Section:** All questions of the demographic section were clear and no updates

Table 7.1: Special Education Teachers' Negative Comments on The Questionnaire

Special Education Teachers' Negative Comments	Our Comments
Some questions are similar (repeated). So, rephrasing could be an option.	Some questions were asked twice; One was closed while the other was open-ended. The closed question provided predetermined options from which the teacher had to choose while the open-ended question gave the teacher space to answer freely. The two questions were identical so that the teacher knew we want a different answer from the previous options.
A lot of questions to complete.	To collect information as much as possible.
Merge each question with its "WHY" to decrease the length of the questionnaire.	Splitting such questions into two parts will force the special education teacher to answer both parts by providing two answer boxes.
Repeat some questions in a different form to check the reliability of the answers.	This will increase the size of the task and will result in an insufficient number of responses.

were needed.

- **Dyslexia Section:**
  - Three questions were modified by either changing keywords or adding more explanation.
  - The options of another three questions were updated by either adding more options or splitting a current option into two.
  - One question was deleted and another was added.
- **Interactive Educational Tool Section:**
  - One question was rephrased.
  - The options of another question were updated by adding more options.

Overall Results:. Eleven modifications were applied to the initial version of the questionnaire based on feedback (see Table 7.2). The details of these modifications are available in Appendix I.

Table 7.2: Number of Questions in The Questionnaire Affected by The Pilot Results

Questionnaire Section	Number of Questions			
	Deleted	Added	Rephrased	Total
Demographic	0	0	0	0
Dyslexia	1	1	6	8
Interactive Educational Tool	0	0	2	2
Ending	0	1	0	1
Total				11

7.2.6 Questionnaire Final Version

Based on the pilot results, the final version included 41 questions instead of 40 as in the initial version (Appendix J):

- **Demographic Section:** this section contained nine demographic questions about the special education teachers such as academic level, gender and years of teaching experience. It, also, verified that the person responding to the questionnaire is a special education teacher.
- **Dyslexia Section:** this section contained 22 questions to determine the common reading and non-reading difficulties that learners with Arabic dyslexia face and how the likelihood that their dialect or their first (non-Arabic) language affects their dyslexia. It, also, verified that the special education teacher had encountered dyslexia during their teaching journey.
- **Interactive Educational Tool Section:** this section contained nine questions to identify any technical features that special education teachers suggest to either include or avoid in the design of interactive educational tool.
- **Ending Section:** this section contained a single ending question to give the special education teacher the opportunity to add anything they think is important and not covered.

7.3 Data Collection

The questionnaire was sent in the form of a MS Forms link to special education teachers via WhatsApp, Telegram and Twitter. Two hundred and sixty-three participants responded to the questionnaire. They went through two filters to ensure that the questionnaire was answered by the correct participants (special education teachers who have taught learners with Arabic dyslexia). These filters were (see Figure 7.4):

- *Are you a special education teacher?* This question was used to extract only the special education teachers and enable them to continue with the questionnaire. Only 157 out of 263 respondents were special education teachers.
- *During your teaching journey, have you ever encountered any students with dyslexia?* This question was used to extract only the special education teachers who have taught learners with dyslexia. Only 101 special education teachers had actually taught learners with dyslexia and were able to complete the whole questionnaire.

So, 101 special education teachers whose data was collected and analysed. Figure 7.5 illustrates their demographic information.

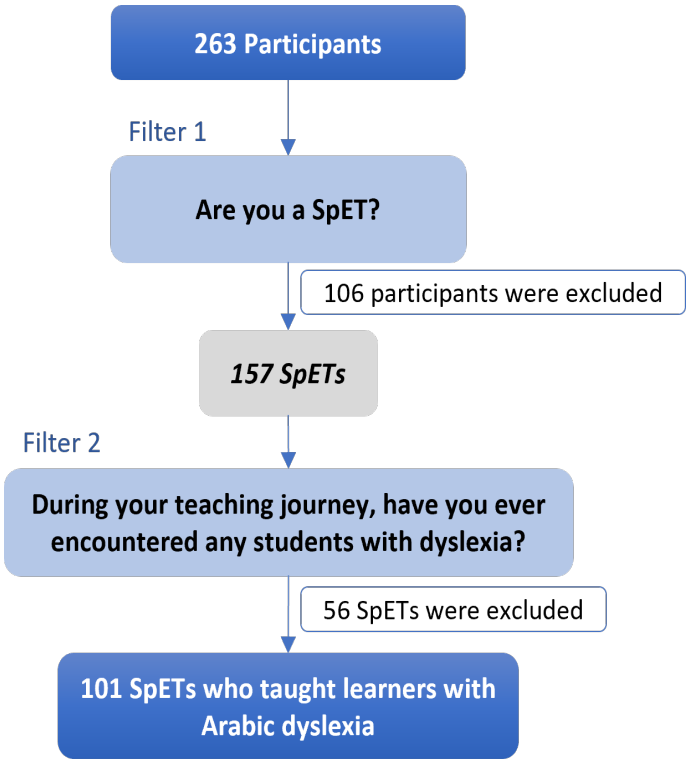


Figure 7.4: Filters Applied to Responses to Exclude Noise

7.4 Results and Discussions

The questionnaire contained both closed and open-ended questions. The closed questions were analysed using IBM SPSS Statistics software. The open-ended questions were analysed manually using Thematic Content Analysis (Braun and Clarke, 2006). The results of the analysis are classified into common dyslexia reading difficulties, common dyslexia non-reading difficulties, dyslexia difficulties suggested to be targeted by special education teachers, teaching strategies, interactive educational tool and additional findings. Each class is presented below. It should be noted that we discarded responses that were either empty or "**I do not know**" responses.

7.4.1 Common Dyslexia Reading Difficulties

The common dyslexia reading difficulties were explored, from the special education teachers' perspective, by:

- Listing four common dyslexia reading difficulties plus an "other" option (see Table 7.3).
- Giving the opportunity to add any other common dyslexia reading difficulty they encountered among their learners.

The special education teachers' responses to the common dyslexia reading difficulties list is given in Table 7.3. Vowel letter dyslexia is the most common dyslexia reading difficulty, followed by letter position dyslexia (which is inline with (Friedmann and Haddad-Hanna, 2014)) and finally short vowel dyslexia.

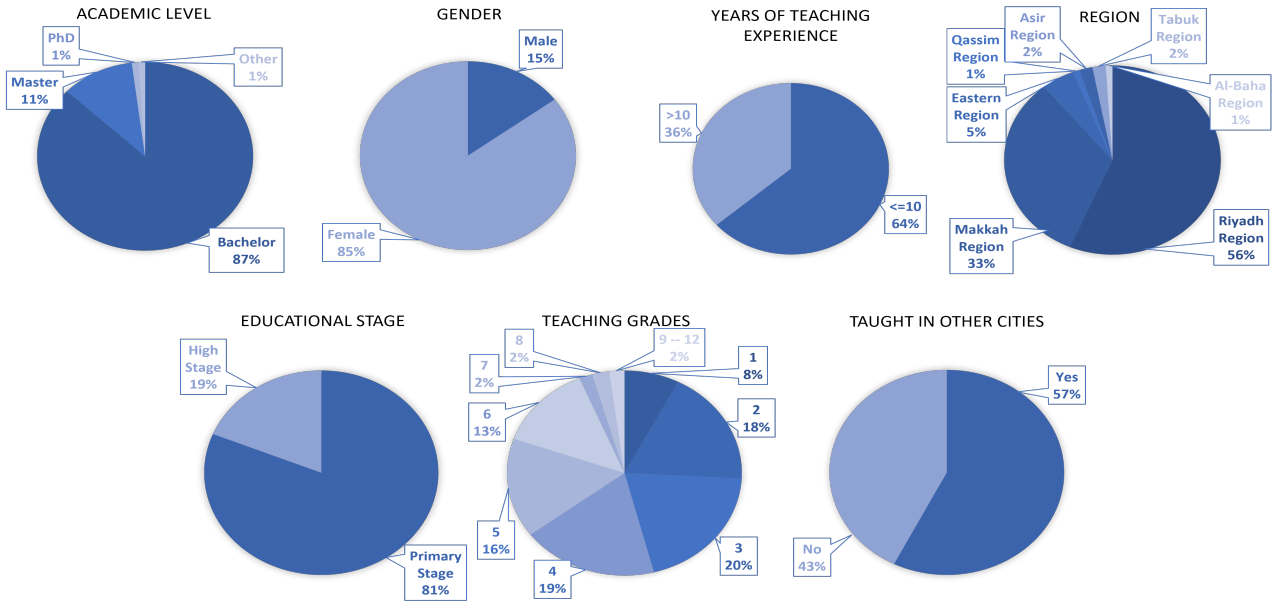


Figure 7.5: Demographic Information of Special Education Teachers in The Exploratory Questionnaire

Table 7.3: Common Dyslexia Reading Difficulties From Special Education Teachers' Perspective

Common Dyslexia Reading Difficulties	Percent of Responses
Difficulty 1: Migrating the letters within a word that results in a known word. E.g. reading the word "Ya'mal" as "Ya'lam".	78.2%
Difficulty 2: Migrating the letters within a word that results in a non-word. E.g. reading the word "Yahmel" as "Yamhel".	64.4%
Difficulty 3: Substitute a short vowel with another short vowel. E.g. reading the word "kotob" as "katab".	69.3%
Difficulty 4: Substitute a long vowel with a short vowel and vice versa. E.g. reading the word "Katab" as "Kaateb".	84.2%
Other Dyslexia Reading Difficulties.	6.9%

However, 6.9% of the special education teachers chose the "other" option and added these dyslexia reading difficulties:

- Reading letters individually without blending their phonemes to form the whole word.
- Difficulty in spelling.
- Mixing between letter phonemes.
- Adding, substituting and deleting letters within a word.
- Changing a word to its synonym: reading by meaning.
- Difficulty in reading syllables that have a Sakin letter. A Sakin letter is a letter with a Sukun diacritic (°) which indicates an un-vowelised letter (Abandah et al., 2015), such as the letter

"ي", in the word "بيْت" illustrated in Table 2.1.

In KSA, male teachers teach male learners and female teachers teach females. Therefore, the special education teachers' gender (male and female) was considered and their responses were re-analysed (see Table 7.4) giving consistent results with those shown in Table 7.3 where vowel letter dyslexia is the most common reading difficulty followed by letter position dyslexia then short vowel dyslexia. The same was found when considering the two largest Saudi cities: Riyadh and Jeddah (see Table 7.5).

Table 7.4: Common Dyslexia Reading Difficulties From Special Education Teachers' Perspective Based on Gender

Common Dyslexia Reading Difficulties	Percent of Male Responses	Percent of Female Responses
Difficulty 1: Migrating the letters within the word that result to a known word. E.g. reading the word "Ya'mal" as "Ya'lam".	73.33%	79.07%
Difficulty 2: Migrating the letters within the word that result to a non-word. E.g. reading the word "Yahmel" as "Yamhel".	46.67%	67.44%
Difficulty 3: Mixing short vowels only. E.g. reading the word "kotob" as "katab".	66.67%	69.77%
Difficulty 4: Mixing between long and short vowels. E.g. reading the word "Katab" as "Kaateb".	80.00%	84.88%
Other Dyslexia Reading Difficulties.	6.67%	6.98%

Table 7.5: Common Dyslexia Reading Difficulties From Special Education Teachers' Perspective Based on City

Common Dyslexia Reading Difficulties	Percent of Riyadh Responses	Percent of Jeddah Responses
Difficulty 1: Migrating the letters within the word that result to a known word. E.g. reading the word "Ya'mal" as "Ya'lam".	80.35%	80.00%
Difficulty 2: Migrating the letters within the word that result to a non-word. E.g. reading the word "Yahmel" as "Yamhel".	67.86%	70.00%
Difficulty 3: Mixing short vowels only. E.g. reading the word "kotob" as "katab".	75.00%	60.00%
Difficulty 4: Mixing between long and short vowels. E.g. reading the word "Katab" as "Kaateb".	85.71%	90.00%
Other Dyslexia Reading Difficulties.	5.36%	10.00%

The justifications given for these choices were analysed and coded manually, giving a total of 123 responses. Forty-six were discarded. The remaining 77 were categorised into: student (53.25%), teachers and teaching (15.58%), reading (23.38%), parents (5.19%) and other (2.60%). In terms of ***students***, a group of teachers claimed that developmental problems, poor attention, focus loss,

problems in visual discrimination and visual perception cause reading difficulties. In terms of ***reading***, student's lack of reading training and their rushing to read were common reasons given. Other teachers mentioned that possible reasons are teacher neglect, teacher's lack of familiarity with dyslexia and poor foundation and teaching. Further, ***parents*** were reported as affecting their children's reading ability by their neglect, and by not correcting their children's mistakes. Sometimes delays in intervention and problem identification were raised.

As mentioned earlier, special education teachers reported other common dyslexia reading difficulties they have encountered. The responses were analysed and coded manually, giving a total of 241 responses. Forty-six were discarded. The remaining 195 responses were categorised into letter, word and sentence level difficulties. In terms of ***letter level***, there was a variety of problems such as pronouncing the name of the letter instead of its phoneme and difficulty in identifying letters. Most of the special education teachers' responses regarding the ***word level*** were symptoms of visual dyslexia. These were adding (4.62%), deleting (14.36%) and substituting letters (consonants not vowels) within a word (17.44%) giving a total of 36.41% of the reading difficulties. Finally, at the ***sentence level***, lack of fluency was the dominant dyslexia reading difficulty given. It is obvious that the most common dyslexia reading difficulty from the special education teachers' perspective is visual dyslexia. However, this conflicts with (Friedmann and Haddad-Hanna, 2014) where visual dyslexia is not common. This could be because the research was conducted in a different Arab country (Palestine) from the one in this research (KSA) with different dialects (AlRowais et al., 2013). Again, the special education teachers justified their choice in 115 reasons. Sixty-two of them were discarded. The remaining 53 were analysed and coded manually into teaching, student, reading, parents and others. 20.75% of these reasons were about the ***teaching*** itself. For instance, using inappropriate teaching strategies and a lack of early intervention. In terms of the ***student***, some of the teachers' justifications include student's developmental problems, genetic origin and lack of diligence. Justifications in terms of the ***reading and parents*** category include a lack of reading and parental interest and unwillingness to enroll their children into the learning difficulty program.

Dialect/First non-Arabic Language

Arabic societies speak different dialects: Najdi, Hijazi, Bedouin, Syrian, etc. Some of these dialects pronounce some of the Arabic letters differently such as pronouncing "Thal" as "Dal" while others migrate letters within the word such as pronouncing "Melaqah" as "Maalagah". Therefore, the special education teachers were asked to what extent they agree that the dialect of learners with Arabic dyslexia affects their reading. As shown in Figure 7.6, 54.45% of the special education teachers agreed that dialect affected dyslexia reading while 45.54% disagreed. (AlRowais et al.,

2013) reported that dyslexia is affected by Arabic culture and dialects.

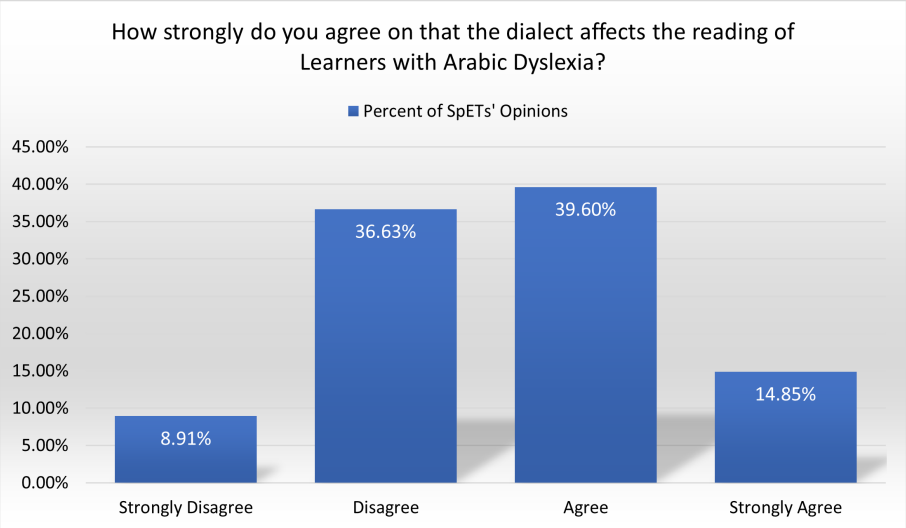


Figure 7.6: How Do Dialects Affect Individuals with Dyslexia From Special Education Teachers' Perspective?

Then, teachers were asked to determine the dialects that they believed either affected or did not affect dyslexia reading. Their responses are illustrated in Table 7.6. A majority of the special education teachers agreed that the Saudi dialects generally affect dyslexia reading especially the Bedouin dialect.

In addition, some learners with Arabic dyslexia, who study in KSA, are Saudis by nationality but not by origin. They may came from other Arab countries (e.g. Syria and Egypt) or from non-Arab countries (e.g. Pakistan and Indonesia). Thus, the non-Arab learners might speak their original language as their first language instead of Arabic. Special education teachers were asked if they have taught non-Arab learners with Arabic dyslexia. Only 6% of them, all female, taught non-Arab learners with Arabic dyslexia. These were originally from Somalia, Pakistan, Malaysia, India, Ethiopia, and Germany.

Frequency of Letter Position Dyslexia

In the literature, letter position dyslexia is the most common Arabic dyslexia type among learners with Arabic dyslexia (Friedmann and Haddad-Hanna, 2014). But, in practice, letter position dyslexia was rare -almost none- among these learners in Riyadh schools. Therefore, the special education teachers were asked if they have encountered letter position dyslexia. 84% of them have encountered letter position dyslexia and reported that letter position dyslexia was frequent in their cities (for reasons presented in Table 7.7). 70.6% of these teachers reported that teaching using inappropriate teaching strategies led to the frequency of letter position dyslexia. However, 18.8% of them chose the "other reasons" option and specified reasons such as developmental problems, cognitive impairment, reading from memory and malfunction of the brain.

Table 7.6: Influence of Dialect Type on Reading of Dyslexia

Strongly Agree	Agree	Total	Dialect Type	Disagree	Strongly Disagree	Total
4	6	10	Saudi (in general)	3	0	3
3	4	7	Najdi	3	1	4
1	6	7	Hijazi	2	2	4
0	0	0	Jeddah	1	0	1
1	0	1	Al-Ahsa	0	0	0
0	1	1	Qatif	0	0	0
1	0	1	Easter region	0	0	0
0	0	0	North region	0	0	0
0	2	2	South region	0	0	0
0	2	2	Jazan	0	0	0
0	11	11	Bedouin	1	1	2
1	0	1	Arabic (not Saudi)	1	1	2
1	0	1	Syria Region	0	0	0
2	3	5	Syria	0	0	0
1	0	1	Iraq	0	0	0
2	2	4	Egypt	0	0	0
1	2	3	Sudan	0	0	0
1	2	3	Yemen	0	0	0
1	0	1	Morocco	0	0	0
1	3	4	NA	7	5	12

Table 7.7: Special Education Teachers' Responses to Reasons for Letter Position Dyslexia Frequency

Reasons for Letter Position Dyslexia Frequency	Percent of Responses
They were not Arabs by origin and speak Arabic as their second language.	11.8%
They were taught using inappropriate teaching strategies.	70.6%
They were originally Arabs but they migrate letters positions within a word in their dialect which affects their reading at school (e.g. Arabs from the Syria region).	16.5%
Other reasons.	18.8%

The special education teachers' responses were re-analysed considering their gender and the two largest Saudi cities (Riyadh and Jeddah). The results were the same and no significant variation was found.

The questionnaire enabled the special education teachers to add any other reasons for letter position dyslexia frequency. Most did not add anything beyond the reasons presented in Table 7.7. The answers of the others were analysed and coded manually into reading/non-reading problems, teaching, external factors and dialect/non-Arabic language. In terms of ***reading problems***, 28.2% of special education teachers mentioned that impulsive reading, reading from memory, random reading and switching phonemes were the dyslexia reading problems that increased the frequency of letter position dyslexia. They, also, mentioned other ***non-reading problems*** such as malfunc-

tion in the brain, focus loss, developmental problems, cognitive impairment, distraction/impaired attention, psychological problems, low levels of self-esteem and memory, spelling and vision problems. 10.6% of the special education teachers mentioned poor teaching in the foundation stage, lack of early intervention and inappropriate teaching strategies as the dominant ***teaching*** problems that led to the frequency of letter position dyslexia. In terms of ***external factors***, 12.9% of the special education teachers reported that elderly parents who do not know about dyslexia, poor parental education, lack of home follow-up, parental disinterest, not practicing Arabic at home and student's lack of diligence have increased letter position dyslexia from their perspective. Finally, one teacher disagreed that the dialect increased letter position dyslexia while one agreed. One last teacher disagreed on the relationship between nationality and dyslexia.

16% of special education teachers had not encountered letter position dyslexia and they reported that letter position dyslexia was infrequent in their cities due to the reasons mentioned in Table 7.8. 50% of these teachers justified that the members of the society pick up mistakes in real-life and correct them. Again, similar justifications to those shown in Table 7.8 were found when the responses were re-analysed taking into account the gender and city of the special education teachers.

Table 7.8: Special Education Teachers' Responses to Reasons for Letter Position Dyslexia Infrequency

Reasons for Letter Position Dyslexia Infrequency	Percent of Responses
They were taught using appropriate teaching strategies.	30.0%
They were taught using Qa'eda Al-Nawraniah.	0.0%
Their dialect was pure and very close to the Standard Modern Language.	20.0%
Self-correction between the society's members who catch this mistake (and other mistakes) then correct them.	50.0%
Other reasons.	0.0%

Similarly to letter position dyslexia frequency, special education teachers were asked to add any other reasons (if any) to the infrequency of letter position dyslexia but no additional reasons were added.

7.4.2 Common Dyslexia Non-Reading Difficulties

The common dyslexia non-reading difficulties that co-occur with dyslexia were also explored by:

- Listing 10 common dyslexia non-reading difficulties plus an "other" option (see Table 7.9).
- Giving the opportunity to add any other common dyslexia non-reading difficulty the special education teachers encountered among their learners.

The special education teachers' responses to the dyslexia non-reading difficulties list are given in Table 7.9. Dictation difficulty is the most common dyslexia non-reading difficulty that was selected.

This is consistent with the literature in other languages (Knivsberg et al., 1999).

Table 7.9: Common Dyslexia Non-Reading Difficulties From Special Education Teachers' Perspective

Common Dyslexia Non-Reading Difficulties	Percent of Responses
Math Difficulty	34.7%
Writing Difficulty	52.5%
Dictation Difficulty	87.1%
Focus Loss	53.5%
Phonological Problems	14.9%
Hyperactivity	30.7%
Vision Problems	8.9%
Problems in differentiating between directions	28.7%
Remembering problems	37.6%
Emotional/behavioural problems (e.g. low self-esteem)	28.7%
Other Non-Reading Difficulties	1.0%

Similarly to the "Common Dyslexia Reading Difficulties", the special education teachers' responses were re-analysed considering their gender and city and no significant variation was found. Again, the teachers' justifications for their choices were analysed and coded manually, giving a total of 105 responses. Fifty-five of them were discarded leaving 50. 54% of the remaining responses cited that the previous non-reading difficulties were chosen because they are related to the reading difficulty and dyslexia. Other reasons were reported such as parents' refusal to enroll their children in the learning difficulty program, student's lack of diligence, developmental problems, lack of interest, and inappropriate teaching strategies.

As mentioned earlier, the special education teachers were able to add any other common dyslexia non-reading difficulties. The 101 responses were analysed, coded manually, giving a total of 224 responses where 172 were discarded leaving 52. The majority of the responses (26.92%) included attention deficit which is in line with (Willcutt et al., 2010). Again, they justified their choices giving a total of 106 responses where 57 were discarded leaving 49. 36.73% of these responses cited that they chose these difficulties because they are associated with reading difficulty and dyslexia. Other reasons included student's lack of diligence, developmental problems, lack of interest and inappropriate teaching strategies.

7.4.3 Dyslexia Difficulties Suggested to be Targeted by Special Education Teachers

The special education teachers were asked to list the dyslexia reading or non-reading difficulties they suggest the research to capture. One hundred and one responses were analysed and coded manually, giving a total of 216 responses (see Table 7.10). The majority of the responses suggested reading difficulties. The next difficulty was spelling, due to the relationship between reading and spelling

skills. The responses targeting the reading difficulties were analysed and found that "changing a letter to another one" scored the largest number (22.35%). In other words, substituting letters within the word (especially similarly shaped letters) was the dominant dyslexia reading difficulty. Then, "difficulty with reading comprehension" (12.94%) followed by "deleting letters from the word" (10.95%) followed by "reading fluency, mixing between short and long vowels (vowel letter dyslexia) and migrating letters within the word (letter position dyslexia)" (7.06%). Then, their justifications were analysed and coded manually, giving a total of 108 responses. The majority of the respondents suggested the previous reading difficulties to be focused on due to their frequency (29.62%) and importance (10.19%), to overcome them (10.19%) and their essence in reading correctly and learning other subjects (6.48%). 18.81% of the special education teachers did not justify their choices.

Table 7.10: Reading and Non-Reading Difficulties for Addressing From Special Education Teachers' Perspective

Difficulty	Percent of Responses
Reading Difficulty	39.35%
Spelling Difficulty	10.19%
Writing Difficulty	6.02%
Math Difficulty	4.17%
Memory Problems	7.40%
Attention Deficit	4.17%

7.4.4 Teaching Strategies

The questionnaire also explored the teaching strategies that improved the learning of learners with Arabic dyslexia from the special education teachers' perspective. Their responses were analysed and coded manually giving a total of 251 responses. Sixty-four were discarded leaving 187 responses that suggested 47 different reading teaching strategies. The top five teaching strategies given are; Hierarchical teaching strategy (8.56%), Modeling teaching strategy (6.95%), Word Analysis teaching strategy (5.88%), Role play teaching strategy (5.35%) and Task analysis and Analytical method teaching strategies (4.81%). Then, the teachers justified their answers which were also analysed and coded manually giving 134 responses. Twelve responses were discarded leaving 122 responses. The majority of the justifications for choosing the previous teaching strategies cited teachers' experience, ease of use, student reading improvement, attracting students' attention and targeting their senses.

7.4.5 Interactive Educational Tool

The special education teachers' opinions about using an interactive educational tool as an aid for training rather than just using a textbook were obtained. Their answers are illustrated in Figure 7.7. 96.04% of them agreed that using an interactive educational tool as an aid for training is better than just using a textbook.

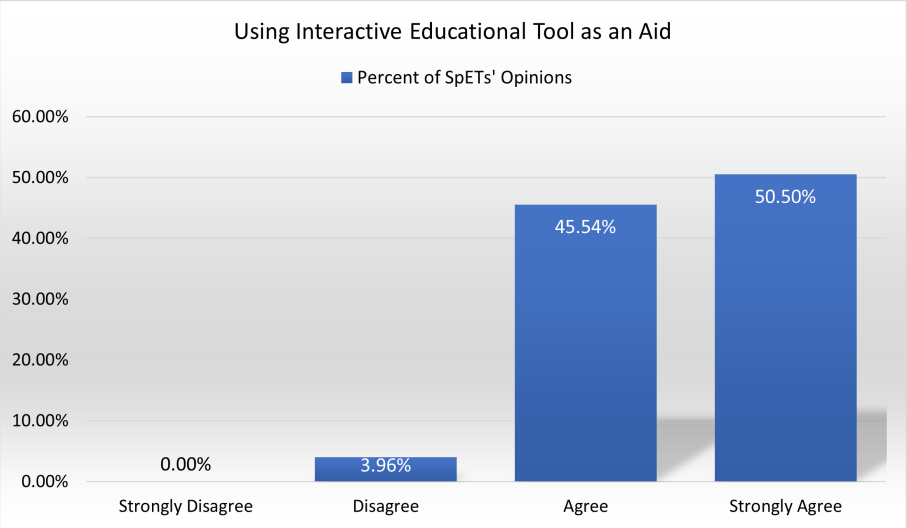


Figure 7.7: Using an Interactive Educational Tool From Special Education Teachers' Perspective

These teachers justified their choice by giving 127 responses where eight were discarded to decrease the responses to 119. There was a variety of reasons to use the interactive educational tool related to different aspects; student (38.66%), interactive educational tool (34.45%), reading skill (12.61%), textbook (10.08%), and other (4.20%). In terms of ***student***, most of the teachers reported that the interactive educational tool attracts the student's attention and focus and increases their motivation. There were also a variety of justifications related to ***interactive educational tool*** itself. For instance, interactive educational tool is diverse, effective and interactive, simplifies information and targets a specific problem. Regarding the reasons related to the ***reading skill***, teachers have mentioned that interactive educational tool improves, encourages, helps, and simplifies reading. Moreover, there were other reasons related to the ***textbook***. The dominant justification is that the textbook does not suit the student's needs and abilities.

Technical Features

The interactive educational tool section also explored the features that the special education teachers think are useful to be included within the design of interactive educational tool. Their choices are shown in Figure 7.8. The majority of special education teachers (87.1%) suggested adding both audio and image to the design of interactive educational tool. This is consistent with the cognitive theory of multimedia learning discussed in Section 4.5.1. It is also recommended by (Benmarrakchi et al., 2017b) to use the multisensory approach since learners with dyslexia prefer the visuospatial/kinesthetic style (Exley, 2003). A few teachers (31.7%) suggested using the points and a progress bar. However, this contradicts with (Dymora and Niemiec, 2019) where points are considered to be one of the main elements for motivating users.

In addition, the special education teachers were able to add any other useful features not listed in Figure 7.8. Their responses were analysed and coded manually giving a total of 154 responses where

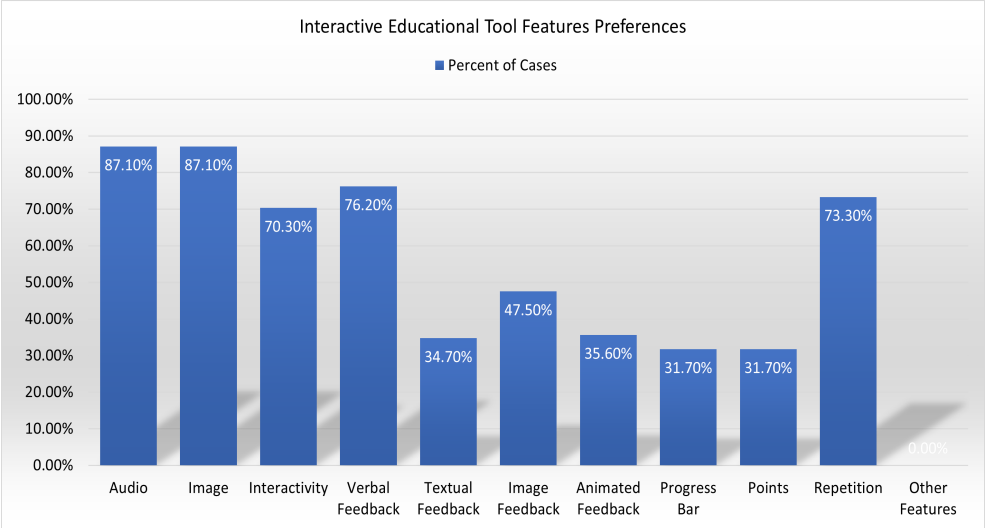


Figure 7.8: Interactive Educational Tool Features Suggested to be Embedded From Special Education Teachers' Perspective

78 were discarded. 71.05% of the remaining 76 responses were features related to the interactive educational tool interface and functionality and 28.95% were features related to the students. In terms of ***interface***, a majority suggested using colours and special/cartoon characters whereas, in terms of ***functionality***, a majority suggested including direct and automatic correction. However, 86.36% of the responses that targeted ***students*** were directed to students' emotions. For instance, they suggested that the educational tool should be attractive, encouraging, motivating and engaging.

The teachers justified their choices in 111 responses where 40 were discarded. The remaining responses were analysed and coded manually into the student (60.56%), reading (14.08%), interactive educational tool features (11.27%), teacher experience (7.04%), memory (5.63%) and others (1.41%). 62.79% of the responses that targeted the ***student*** were directed to their emotions (62.79%). For instance, the teachers chose these features (colours, large font, interaction, feedback and modelling strategy) to motivate the students and attract their attention. In terms of ***reading***, a majority of teachers chose the previous features because they help students in reading.

The features that the special education teachers suggest to avoid were also explored. Their responses were analysed and coded manually giving a total of 180 responses. Forty-six of them were discarded. Most of the remaining responses targeted colour (22.40%), image (12.80%), audio (12.00%) and other features. Most teachers suggested avoiding using many colours and annoying/unclear ones, whereas in terms of ***images***, they suggested avoiding using many and distracting images. In terms of ***audio***, they suggested avoiding the use of loud and distracting sounds. There were a variety of different responses that were included in the ***other interactive educational tool features*** category such as avoiding long learning periods, distraction, small fonts, and complexity.

This is consistent with the guidelines of the British Dyslexia Association (BDA) (BDA, 2018) where distracting surroundings should be avoided.

Finally, the teachers justified their decisions in 123 responses (after coding and analysis) where 25 were discarded leaving 98. The majority targeted the student, especially their emotions (73.24%). Teachers suggested avoiding features in order to: avoid distracting students, simplify their reading, avoid complexity and focus on the goal to be achieved.

Teaching Strategies

Finally, the special education teachers were given the opportunity to suggest teaching strategies they would like to be included within any interactive educational tool. Their responses were analysed and coded manually giving a total of 171 responses where 87 were discarded. The remaining 84 determined 30 different teaching strategies. The top five strategies given are: Repetition (14.29%), Learn by play (11.90%), Modelling and simulation (10.71%), Multi-sensory (9.52%), and Word Analysis (5.95%).

Then, the teachers' justifications were also analysed and coded manually, giving 119 responses where 34 were discarded. The majority of the remaining 85 responses targeted the student and the teaching strategy. In terms of ***student***, the teachers suggested these teaching strategies to increase the student's motivation and attract their attention. In terms of ***teaching strategies***, the justifications included that these teaching strategies were beneficial, effective, simplified reading and because of previous good results.

7.4.6 Additional Findings

At the end of the questionnaire, the special education teachers were given a space to add anything else they think is important. 75.25% of the 101 special education teachers did not add anything. However, the remaining special education teachers added these points:

- Learners with dyslexia are slow learners, with low motivation, need time to learn and must be psychologically prepared to receive any information.
- The progress of learners with dyslexia becomes slower if they are also diagnosed with speech disorders.
- The rise and fall of the confidence of learners with dyslexia positively and negatively affects their progress in the session.
- Learners with dyslexia should be taught individually or in small groups (2-4) in a separate room at an average of two sessions weekly.
- The chronological age, needs, strengths, weaknesses, preferences and learning styles of learners with dyslexia should be considered when introducing any teaching tool.

- The abilities of learners with dyslexia are different.
- The individualised plan for learners with dyslexia should include both their unmastered skills and the grade level skills they must master.
- Sometimes, direct methods are more beneficial than using tools when teaching a new reading skill. Then, the tool can be used for mastering that skill.
- The skill should be segmented into small fragments when teaching.
- The teacher should be patient with the learner, care for them and help them.
- The task should be designed in a way that they can complete it and gradually increase its complexity.
- Involving parents in the learning process is very important.

7.4.7 Summary

To summarise, the questionnaire explored the practice from special education teachers' perspective and found that:

- Vowel letter dyslexia and visual dyslexia are common reading difficulties among Saudi learners with Arabic dyslexia due to their, for instance, developmental problems, poor attention, lack of reading training and the use of inappropriate teaching strategies.
- Along with vowel letter dyslexia and due to the impact of Arabic dialect on dyslexia reading symptoms (AlRowais et al., 2013), visual dyslexia is considered a common Arabic dyslexia type in Saudi primary schools.
- Letter position dyslexia is one of the common Arabic dyslexia types among Saudi learners with Arabic dyslexia, regardless of their city and gender, because they were taught using inappropriate teaching strategies. However, this was not true when Experiment One was conducted in Riyadh schools where letter position dyslexia was rare among the learners. A possible explanation for this is that special education teachers (according to their responses in the questionnaire) might experience letter position dyslexia among the learners in their writing, not in their reading. For instance, writing the word "form" instead of "from". Therefore, further research in this area by special education researchers is needed to prove/disprove that letter position dyslexia is common as a reading problem among Saudi learners.
- Vowel letter dyslexia and short vowel dyslexia are common dyslexia reading difficulties among Saudi learners with Arabic dyslexia.
- Dictation difficulty and attention deficit are the common non-reading difficulties among Saudi learners with Arabic dyslexia.

- Hierarchical, Modelling, Word Analysis, Role play, Task analysis and Analytical method teaching strategies are the top teaching strategies suggested being used because they improve student's reading and attract their attention.
- The majority of special education teachers chose both audio and image components to be included in the interactive educational tool design to attract student's attention whereas the progress bar and points were chosen by a few teachers.
- Using colours and special characters in the design of interactive educational tool is preferable while loud sounds and distracting colours should be avoided.

7.5 Conclusion

The results of the first two experiments of this research were not statistically significant. One possible reason for this is that we built our understanding of the difficulties faced by learners with Arabic dyslexia based on the literature (Friedmann and Haddad-Hanna, 2014) that has not been consistent with practice. This led us to understand the common difficulties faced by these learners in practice from the point of view of experts (special education teachers) in order to combine our understanding from these two perspectives: literature and practice.

Vowel letter dyslexia and visual dyslexia were common dyslexia reading difficulties encountered by special education teachers in practice and identified as Arabic dyslexia types in the literature (Friedmann and Haddad-Hanna, 2014). Therefore, the final experiment targeted these two Arabic dyslexia types. More details are available in the next chapter.

Chapter 8

Adapting Training Material to Learners' Arabic Dyslexia Type

8.1 Introduction

The previous two experiments, detailed in Chapters 5 and 6, targeted vowel letter dyslexia and short vowel dyslexia. However, there were no statistically significant differences in terms of learners' learning gain or satisfaction between the vowel letter dyslexia and short vowel dyslexia groups. An exploratory questionnaire was designed to explore practice from the perspective of special education teachers in order to understand the common difficulties faced by learners with Arabic dyslexia. The analysis of the questionnaire results revealed that vowel letter dyslexia and visual dyslexia are common Arabic dyslexia types in those Saudi primary schools targeted. So, the third and last experiment targeted vowel letter dyslexia and visual dyslexia taking into account the lessons learned from the first two experiments, to understand the effect of adaptation. The details of this experiment are introduced in this chapter along with its results.

8.2 Experiment Three

This experiment was conducted to understand the impact of adapting training material to learners' Arabic dyslexia type on their reading performance, satisfaction and behaviour. The experiment targets vowel letter dyslexia and visual dyslexia. The training material of the ***DysTypeTrain*** system used in Experiment Two was modified to fit the aim of this experiment. It was chosen to target both vowel letter dyslexia and visual dyslexia. In terms of ***vowel letter dyslexia***, the training material combined the three essential short vowels (fat-ha "/a/", kasra "/i/", dammah "/u/"), اَ ، اِ ، اُ and long ones (alef "a", ya-a "i", waw "u"), أا ، ي ، و, progressing from simple words (i.e. three-letter words with only fat-ha short vowel and alef long vowel) to advanced ones (i.e. three-/four-letter words containing all three short vowels and all three long vowels) as illustrated

in Table 8.1.

Table 8.1: Training Material of Vowel Letter Dyslexia in Experiment 3

Activity	Content							
	Short Vowels			Long Vowels			#Letters within a word	
	Fat-ha	Kasrah	Dammah	Alef	Yaa	Waw	3	4
1	✓			✓			✓	
2	✓			✓				✓
3	✓	✓			✓		✓	
4	✓	✓			✓			✓
5	✓		✓			✓	✓	
6	✓		✓			✓		✓
7	✓	✓	✓	✓	✓	✓	✓	✓
8	✓	✓	✓	✓	✓	✓	✓	✓

In terms of ***visual dyslexia***, the training material started with three-letter words where their choices resulted from adding only a letter to the target word and ended with a combination of three-, four- and five-letter words where their choices resulted from either letter addition, letter deletion or substituting a letter with another similar in shape or sound as shown in Table 8.2.

Table 8.2: Training Material of Visual Dyslexia in Experiment 3

Activity	Content					
	Error Type			#Letters within a word		
	Add	Delete	Substitute	3	4	5
1	✓			✓		
2	✓				✓	
3		✓			✓	
4		✓				✓
5			✓	✓		
6			✓		✓	
7	✓	✓	✓	✓	✓	✓
8	✓	✓	✓	✓	✓	✓

Further, the incorrect words were chosen to target the difficulties of the Arabic dyslexia type (vowel letter dyslexia/visual dyslexia). In terms of ***vowel letter dyslexia***, the incorrect words were similar to the correct word in terms of letters and positions. They differed only from the correct word in either deleting a long vowel (changing long to short vowel), adding a long vowel (changing short to long vowel) or changing the position of a long vowel as shown in Figure 8.1. In terms of ***visual dyslexia***, the incorrect words were similar to the correct word in terms of letters and positions. They differed only from the correct word in either adding a letter, deleting one or substituting a letter with another similar in shape or sound as shown in Figure 8.2.

Based on the discussions of Experiments One and Two in Section 6.3, these updates were applied to this experiment:

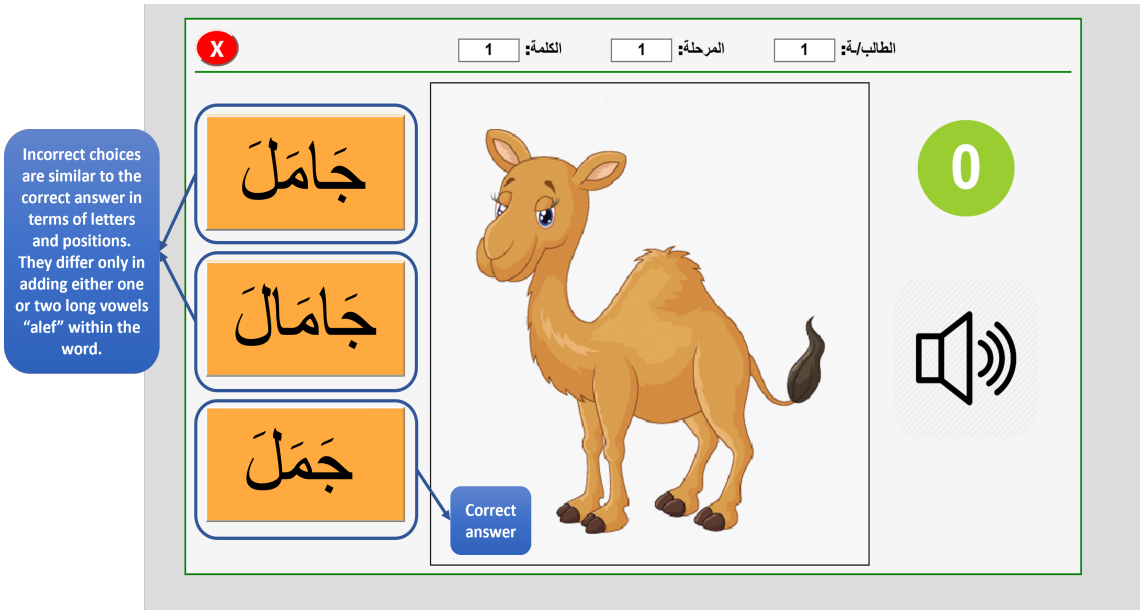


Figure 8.1: Example of Incorrect Choices for Vowel Letter Dyslexia in Experiment 3

- Repetitions were not included because they may have affected the results of the previous two experiments. Therefore, all learners were able to unlock the next activity even though they did not score 80%.
- The learner's incorrect choices were not read aloud by the system, as some learners did not like this feature and skipped to the next exercise.
- Two versions of the system were designed and named: ***adaptive version*** and ***non-adaptive version***. The ***adaptive version*** offered training material adapted to the learner's Arabic dyslexia type whereas the non-adaptive version offered generic training material regardless of the learner's Arabic dyslexia type.
- The learners in both groups in the previous experiments were highly satisfied with the system. This indicated that they liked the system and were motivated. However, we needed to measure the satisfaction in more detail. For this purpose, the satisfaction in e-learning questionnaire, illustrated in Appendix E, was used (more details regarding this questionnaire is available in Section 3.3.3). The reasons for choosing this particular tool was detailed in Section 4.5.2.
- As the teaching in Saudi schools during the period of running this experiment was conducted remotely, the experiment was conducted entirely remotely.
- The generalisation performance was assessed to evaluate the effectiveness of the ***DysTypeTrain*** system (Nist and Joseph, 2008). This was achieved by measuring the learning gain of unseen words in both conditions (adaptive and non-adaptive groups). To measure such a metric, the pre- and post-tests included seen and unseen words, where the seen words are seen by the learner through the system while the unseen words are not seen.

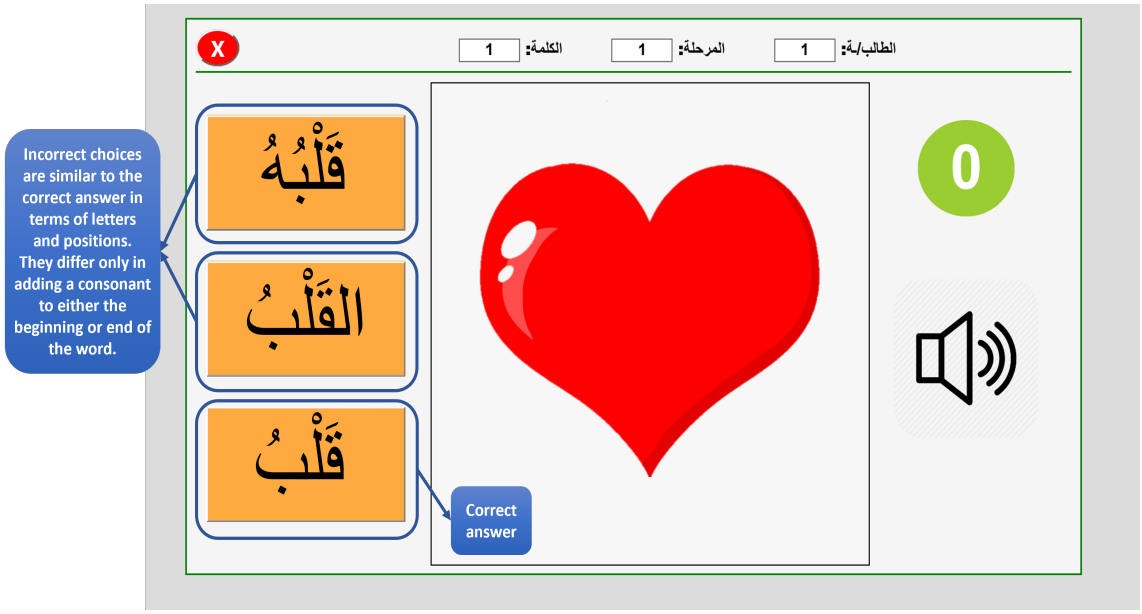


Figure 8.2: Example of Incorrect Choices for Visual Dyslexia in Experiment 3

8.2.1 Hypotheses

Four hypotheses were tested:

H3.1: Adapting training material to learners' Arabic dyslexia type achieves significantly greater learning gain compared to non-adapted material.

H3.2: Adapting training material to learners' Arabic dyslexia type achieves significantly greater learning gain of seen words compared to non-adapted material.

H3.3: Adapting training material to learners' Arabic dyslexia type achieves significantly greater learning gain of unseen words compared to non-adapted material.

H3.4: Adapting training material to learners' Arabic dyslexia type achieves significantly greater learner satisfaction compared to non-adapted material.

8.2.2 Procedure

This experiment followed exactly the same procedure as Experiments One and Two as detailed in Section 5.2.2. However, this experiment was designed using adaptive (experimental) and non-adaptive (control) groups. Both groups included learners with either vowel letter dyslexia or visual dyslexia. The adaptive group used the adaptive version of the system while the non-adaptive group used the non-adaptive version. The framework of this experiment is shown in Figure 8.3

8.2.3 Participants

Since the experiment was conducted remotely, there was no need to attend schools in person and thus we could recruit male and female learners to increase the number of participants. We were

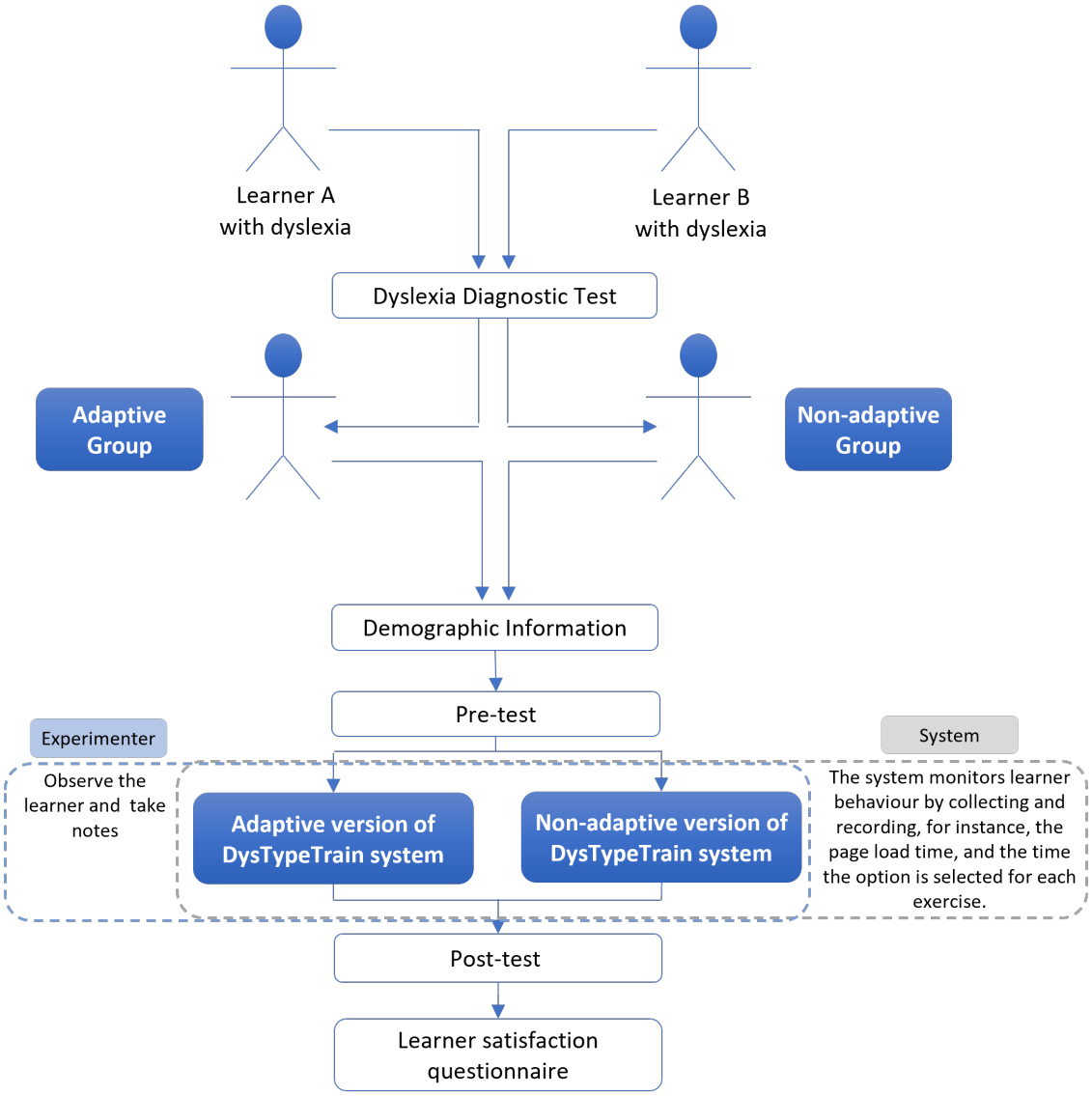


Figure 8.3: Framework of Experiment 3

able to reach them via our contacts. 54 male and female, native Arabic-speaking learners, already diagnosed with Arabic dyslexia, were recruited from different Saudi primary schools. The age of learners was from 7 to 13 years (Grades two to six) (see Figure 8.4). All had previous experience with electronic devices. Learners were assigned to either the adaptive group (n=28) or the non-adaptive group (n=26). There was no statistically significant difference in the initial reading skill level (measured by the pre-test) between the two groups.

8.2.4 Results and Discussions

The groups of learners were homogeneous in terms of Arabic dyslexia type, number of learners, initial reading level and age. The mean age of the adaptive group was 10.25 (Standard Deviation = 1.38) whereas for the non-adaptive group it was 10.23 (Standard Deviation = 1.42). The learners were encouraged to take part in the experiment to improve their reading. Quantitative and qualitative results are detailed below.

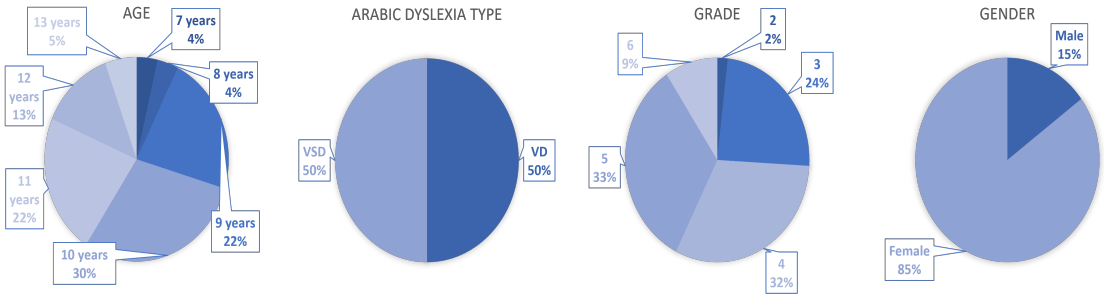


Figure 8.4: Demographic Information of Participants in Experiment 3

8.2.4.1 Quantitative Results

The pre- and post-tests and the learner satisfaction scores were collected to measure both the learning gain (overall learning gain and learning gain of seen and unseen words) and learner satisfaction. Table 8.3 shows the mean and standard deviation of these data.

Table 8.3: Means and Standard Deviations (SD) of Pre- and Post-Test, Learning Gain (LG) and Learner Satisfaction (LS) Scores for Both Groups in Experiment 3, *(SW = Seen Words, UW = Unseen Words)*

Group	N	Pre-test		Post-test		LG		LG of SW		LG of UW	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Adaptive Group	28	2.43	1.77	4.61	2.56	2.18	1.81	1.61	1.37	0.57	1.23
Non-adaptive Group	26	2.27	2.27	3.77	2.44	1.50	1.03	0.85	0.83	0.65	0.94

Learning Gain. Hypothesis H3.1 was tested in this experiment. Figure 8.5 shows that the mean learning gain scores of both the adaptive and non-adaptive groups were positive. This indicates that the reading of both groups was improved. This suggests that the system and the training material were effective and the learner's learning was enhanced. However, it should be noted that the learners were also taking conventional lessons over the period of the experiment, therefore, we should be cautious in drawing any conclusion. It also should be noted that Arabic societies speak different Arabic dialects. Some of these dialects are close to Modern Standard Arabic while others are far, which may affect the manifestation of Arabic dyslexia (AlRowais et al., 2013) and therefore the reading of the learners. Also, Modern Standard Arabic is the Arabic language version that was used in the system as the training material was chosen from the academic textbooks of Saudi primary school (which are written in Modern Standard Arabic).

The mean learning gain of the adaptive group was higher than that of the non-adaptive group, therefore, a statistical test was run to determine any significant difference in the learning gain scores between the adaptive and non-adaptive groups. As there were outliers in the data of the non-adaptive group, as assessed by inspection of a boxplot (see Figure 8.6), the Mann-Whitney U test was used as an alternative to the independent sample t-test. Distributions of the learning

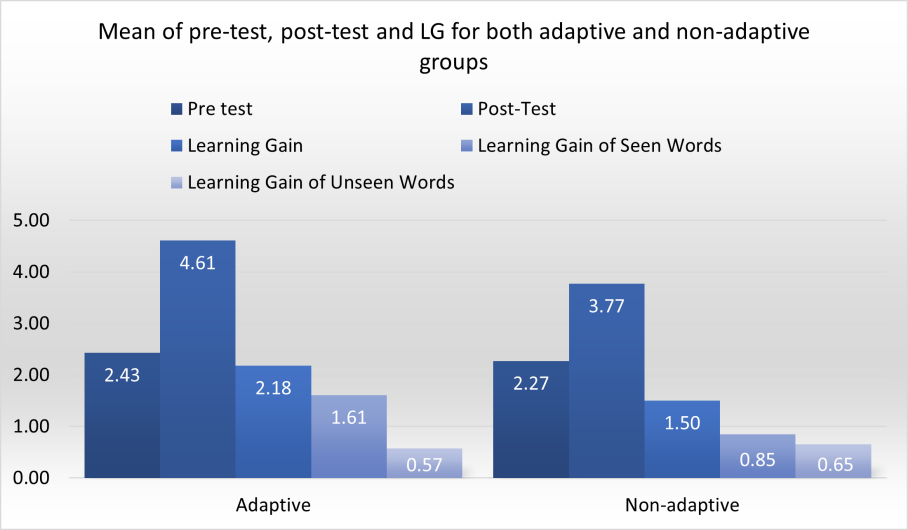


Figure 8.5: Means of Pre- and Post-Test and Learning Gain Scores for Both Groups in Experiment 3

gain scores for adaptive and non-adaptive groups were not similar, as assessed by visual inspection (see Figure 8.7). Therefore, the *mean* of the learning gain scores were compared. The learning gain scores for adaptive (mean rank = 30.32) and non-adaptive (mean rank = 24.46) were not statistically significantly different, U = 443.000, z = 1.404, p = 0.160 > 0.05. This is not the result that was expected and is inconsistent with (Alghabban et al., 2021).

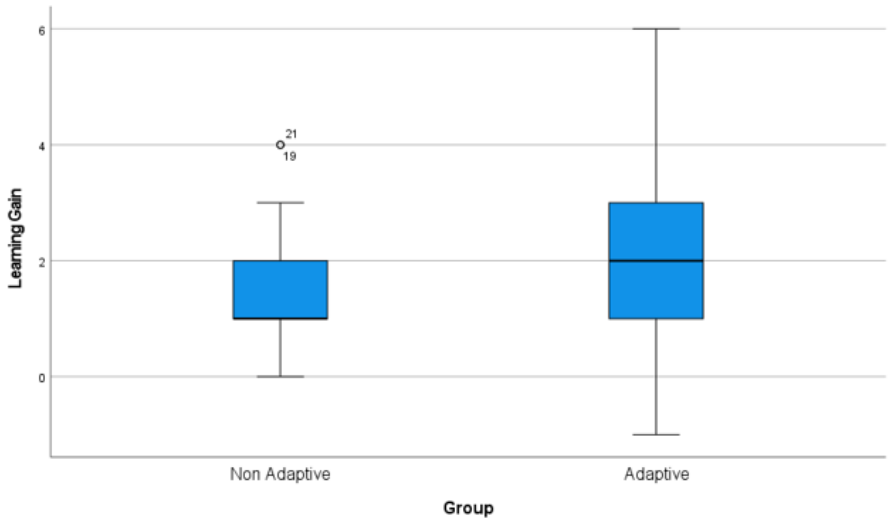


Figure 8.6: Boxplot of Learning Gain for Both Groups in Experiment 3

Learning Gain of Seen Words. To test Hypothesis H3.2, the learning gain score of seen words was measured by subtracting the pre-test score of the seen words from the post-test score of these words. Figure 8.5 shows that the mean learning gain scores of seen words for both adaptive and non-adaptive groups were positive. This indicates that the reading of the adaptive and non-adaptive groups for the seen words was improved because both groups have seen these words in the system and were trained on their correct pronunciation. As the mean learning gain of seen words for

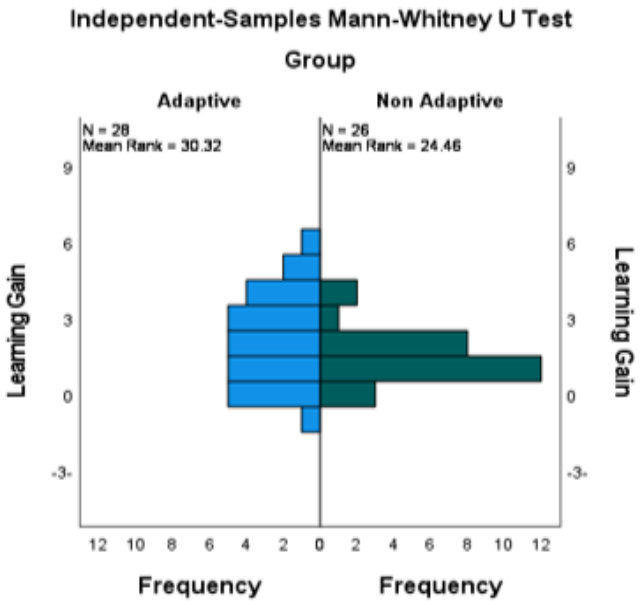


Figure 8.7: Distributions of Learning Gain for Both Groups in Experiment 3

the adaptive group was higher than that of the non-adaptive group, a statistical test was run to determine any significant difference in the learning gain scores of seen words between the adaptive and non-adaptive groups. There were outliers in the data of the non-adaptive group, as assessed by inspection of a boxplot (see Figure 8.8) so, the Mann-Whitney U test was used as an alternative to the independent sample t-test. Distributions of the mean learning gain scores of seen words for both adaptive and non-adaptive groups were not similar, as assessed by visual inspection (see Figure 8.9). Therefore, the *mean* of the learning gain scores were compared. The learning gain scores of seen words for the adaptive (mean rank = 32.23) and non-adaptive (mean rank = 22.40) groups were statistically significantly different, U = 496.500, z = 2.368, p = 0.018 $<$ 0.05. This indicates, that adapting the training material to Arabic dyslexia type leads to significantly greater learning gain of seen words than in the non-adaptive group and therefore, H3.2 is accepted.

Learning Gain of Unseen Words. To test Hypothesis H3.3, the learning gain score of unseen words was calculated for both adaptive and non-adaptive groups. As shown in Figure 8.5, the mean learning gain scores of unseen words for both groups were similar and positive. Whilst this indicates that the reading of both groups for unseen words was improved, it suggests that the system has improved the learners' ability to blend the phoneme of the individual letters within a word and pronounce the whole word correctly. Since the learners in both conditions were at the same level of their initial reading performance (indicated by the pre-test) and the same group of academic level (primary school) and were not trained to read these words, this may explain why they improved similarly and therefore, H3.3 is rejected.

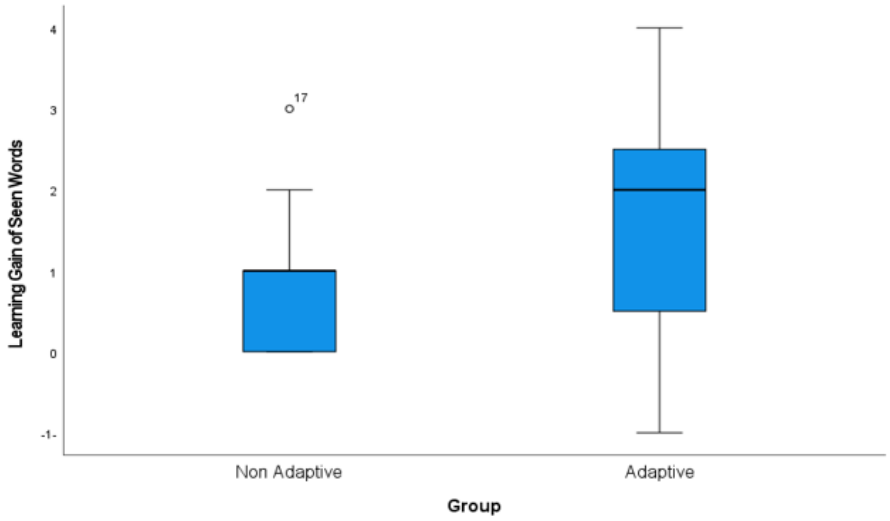


Figure 8.8: Boxplot of Learning Gain of Seen Words for Both Groups in Experiment 3

In summary, the reading performance of the adaptive group improved significantly more than the non-adaptive group for the seen words whereas it improved similarly for the unseen words which affected the overall learning gain statistical results. Therefore, H3.1 is partially accepted, and it can be inferred that adapting the training material to the learner's Arabic dyslexia type leads to significantly better reading than in the non-adaptive condition for only trained (seen) words and no opportunity to conclude that what has been learned can be generalised to other contexts, which in our case is the untrained (unseen) words.

Learner Satisfaction. Learner satisfaction was measured for both groups to test Hypothesis H3.4. The satisfaction in e-learning questionnaire was used (see Appendix E). The questionnaire contained ten questions which were grouped into four sections. A content section with two questions, systems section with three questions, delivery method section with four questions and overall satisfaction section with a single question. The mean learner satisfaction score for each section along with the mean overall satisfaction score for both adaptive and non-adaptive groups are shown in Figure 8.10.

Content Section. The mean learner satisfaction score of the content section for the adaptive group (Mean = 4.48, Standard Deviation = 0.67) is approximately the same for the non-adaptive group (Mean = 4.31, Standard Deviation = 0.75). Thus, both groups were highly satisfied with the content (training material) of the system.

Systems Section. The mean learner satisfaction score of the systems section for the adaptive group (Mean = 4.73, Standard Deviation = 0.42) is approximately the same as for the non-adaptive group (Mean = 4.86, Standard Deviation = 0.28) and therefore both groups were highly satisfied with the usability of the system. This may be because the interface (such as font type, size and colours) of

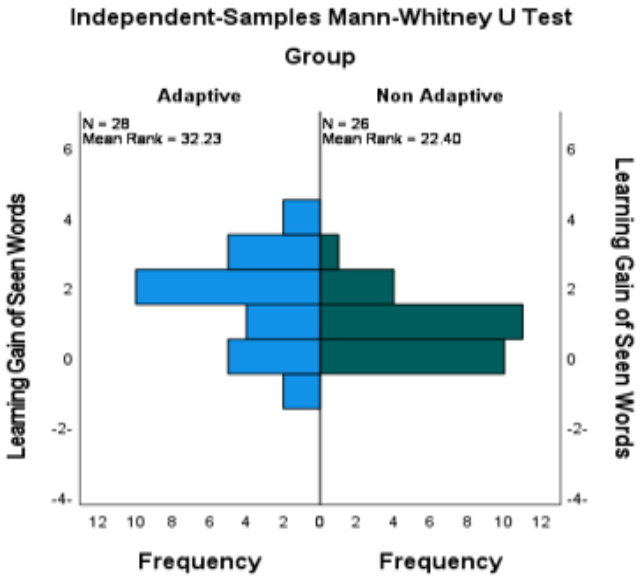


Figure 8.9: Distributions of Learning Gain of Seen Words for Both Groups in Experiment 3

both versions (adaptive and non-adaptive) of the system was the same and the system responded similarly to learners in both versions (such as given feedback). So, both versions are usable at the same level.

Delivery Method Section. Like the previous sections, the mean satisfaction score of the delivery method section for the adaptive group (Mean = 4.72, Standard Deviation = 0.38) is nearly the same as the non-adaptive group (Mean = 4.87, Standard Deviation = 0.18). Again, both groups were highly satisfied with the way the system delivered the content.

Overall Satisfaction Section. The mean satisfaction score of the overall satisfaction section for the adaptive group (Mean = 4.96, Standard Deviation = 0.19) is nearly the same as the non-adaptive group (Mean = 4.89, Standard Deviation = 0.32). In other words, the learners in both groups were, in general, highly satisfied with the system.

Finally, the mean learner satisfaction score for all satisfaction sections (content, systems, delivery method and overall satisfaction) was calculated. The mean for the adaptive group (Mean = 4.70, Standard Deviation = 0.30) is approximately the same for the non-adaptive group (Mean = 4.76, Standard Deviation = 0.26).

As the satisfaction scores of both groups were extremely high and there was, in effect, no opportunity to discriminate between the satisfaction of the two groups, so, it cannot be concluded that adapting training material to Arabic dyslexia types has an effect on the level of learner satisfaction. Therefore, H3.4 is rejected.

This is not the expected result. Since this research studies the effect of content adaptation based

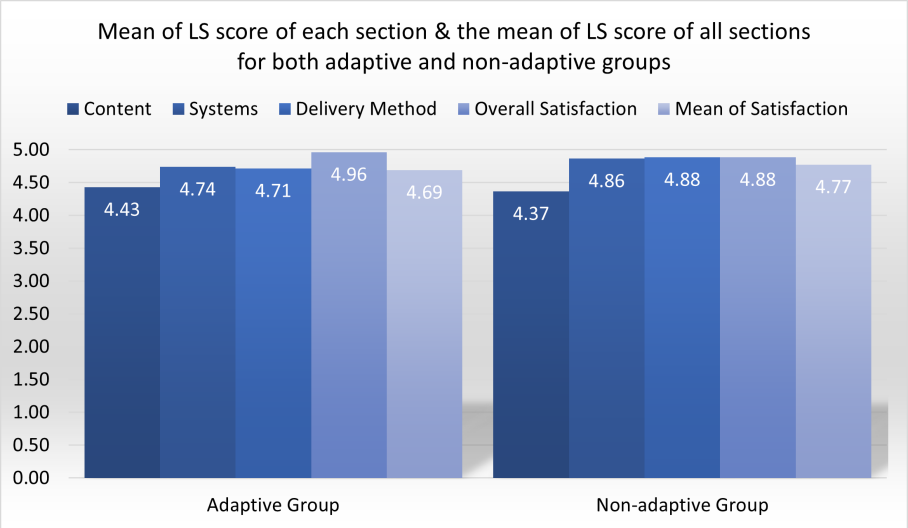


Figure 8.10: Means of Overall Learner Satisfaction and Learner Satisfaction Scores of Each Section for Both Groups in Experiment 3

on Arabic dyslexia type, we believed that there would be a significant result in the content section of the learner satisfaction questionnaire.

From this experiment, it might be clear that we cannot capture the learner satisfaction in detail from young learners. They also seem to tend to choose the more extreme options (Wilson and Conroy, 1999; Sim et al., 2006) and focus more on the system's interface rather than its content.

Finally, all learners regardless of their experimental group were highly satisfied with the system and therefore highly motivated, engaged (Kangas et al., 2017; Alghabban and Hendley, 2020b) and enjoyed using the system (Lin et al., 2017). This might explain why none of the learners dropped voluntarily from the experiment once they have started using the system as high satisfaction leads to continue using the system (Chou and Chen, 2009) and indicates the system's ease of use and usefulness (Lin et al., 2017). Whilst our results conflict with the results of (Alghabban and Hendley, 2020b), this suggests that the way the training material was designed in our experiment and in the experiment of (Alghabban and Hendley, 2020b), possibly explains this contradiction. In our case, the system offers the audio and the image of the training material and the learner chooses the correct choice between three different textual choices. This forces the learner to read the choices and then choose what they think is correct. Whereas in (Alghabban and Hendley, 2020b), the system offers the audio and the text of the training material and the learner chooses the correct image from three pictorial choices. It is a kind of visual discrimination by choosing the image that matches the spoken and written word.

8.2.4.2 Qualitative Results

Again, qualitative data were collected by the experimenter while observing each learner at each session. The thematic map of the observations is illustrated in Figure 8.11.

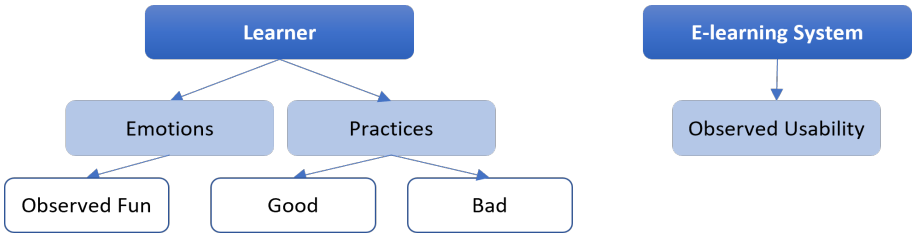


Figure 8.11: Thematic Map of Observations in Experiment 3

Here, the observations were categorised into only learners and e-learning system. There is no experiment mode category as in Experiments One and Two, because this experiment was conducted entirely remotely. In terms of ***learners***, their fun was observed and a checklist was filled during the first experimental session. Table 8.4 illustrates that a majority of learners in both groups were happy and engaged during their interaction with the system for the same reasons reported in the second experiment.

Table 8.4: Observed Fun Results of Experiment 3

Group	Engaged N(%)	Bored N(%)	Happy N(%)	Sad N(%)	Compliment N(%)	Criticism N(%)
Adaptive Group	16(57%)	0(0%)	17(61%)	0(0%)	4(14%)	0(0%)
Non-adaptive Group	15(58%)	0(0%)	19(73%)	0(0%)	6(23%)	0(0%)

On the other hand, most of the learners in both groups did not compliment and/or criticise the e-learning system. Feeling that they were isolated could be a reason for that, as the whole experiment was conducted online. However, some learners did compliment by saying ("**It is really nice**" and "**I liked it**").

Additionally, 79% of the adaptive group and 77% of the non-adaptive group were happy when they answered correctly. Some of them overreacted either verbally by, for instance, saying "**Yyyyyeesss**" or physically by dancing. In the case of choosing incorrectly, 75% of the adaptive group and 85% of the non-adaptive group were sad accordingly. Also, some of them overreacted by saying "**Oh no**" or by hitting their hands or face.

Moreover, the learners followed some good and bad practices that affected their choices positively and negatively respectively (see Table 8.5). It was obvious that spelling out the question word, thinking before answering and re-listening to the question word were widely used by both groups. These practices might help learners to decode the word into its phonemes and then determine its letters, short and long vowels.

On the other hand, the widely followed bad practice by both groups was rushing to answer. Of course, this will often lead them to select wrong answers. The severe reading difficulty experienced

by the majority of these learners can explain the reason for this rush which in turn led them to choose quickly and sometimes randomly to escape reading. Other minor reasons can explain this issue: eating while interacting with the system, moving a lot and waking up directly before using the system.

Table 8.5: Learners Practices in Experiment 3

Practice Type	Practice	Adaptive Group N(%)	Non-adaptive Group N(%)
Good	Spelling out the question word.	27(96%)	26(100%)
	Re-pronouncing the question word.	11(39%)	16(62%)
	Thinking before answering.	28(100%)	25(96%)
	Re-listening to the question word when needed.	25(89%)	23(88%)
	Reading all choices before answering.	4(14%)	2(8%)
	Taking the time to think then answer.	4(14%)	2(8%)
	Being focused.	13(46%)	17(65%)
	Removing the short vowel of the last letter.	1(4%)	0(0%)
Bad	Moving a lot.	8(29%)	4(15%)
	Rushing.	11(39%)	11(42%)
	Sitting in front of TV.	0(0%)	1(4%)

Finally, in terms of the ***e-learning system***, its usability was observed and a checklist was filled during the first experimental session (Ismail et al., 2011). As illustrated in Table 8.6, the sound, image and text were clear for both adaptive and non-adaptive groups. Also, all learners were aware of the functionality of each button. For instance, they knew that the speaker button is for re-playing the question word. Additionally, all learners were aware of their role in the system and its behaviour. Overall, this suggests that the system was usable and efficient.

Table 8.6: Observed Usability Results of Experiment 3

Usability Issue	Adaptive Group N(%)	Non-adaptive Group N(%)
Is sound clear?	28(100%)	26(100%)
Is image clear?	28(100%)	26(100%)
Is text clear?	28(100%)	26(100%)
Choosing correct buttons?	28(100%)	26(100%)
Knowing what is going on?	28(100%)	26(100%)
Not going back?	28(100%)	26(100%)
Knowing what to do?	28(100%)	26(100%)

8.3 Conclusion

This chapter introduced the third and final experiment of this research. It investigated the impact of adapting training material to learners' Arabic dyslexia type on their reading performance, satisfaction and behaviour. Vowel letter dyslexia and visual dyslexia were targeted in this experiment. A mixed-methods approach of qualitative and quantitative data was used. The experiment was

conducted with 54 learners with Arabic dyslexia. Similarly to the previous experiments, the quantitative findings of this experiment showed a positive effect on learning gain and a high level of learner satisfaction regardless of their Arabic dyslexia type. However, there was a statistically significant difference in only the learning gain scores of seen words between the adaptive and non-adaptive groups when a Mann-Whitney U test was used. As in the previous experiments, the qualitative findings of this experiment revealed that the majority of learners were happy and engaged during their interaction with the system. In addition, the learners followed good and bad practices during their interaction with the system that affected their choices positively and negatively respectively. Spelling out the question word, thinking before answering and re-listening to the question word were examples of the good practices, whereas rushing to answer was an example of the bad ones. From the results of this experiment, it was clear that the reading of learners who experienced e-learning content directed to their needs (Arabic dyslexia types in our case) improved better than that of those who experienced generic content which is in line with the results of (Alghabban et al., 2021). Also, the reading of learners in both conditions improved similarly in the case of new words and therefore contradicts the results of (Alghabban et al., 2021) and more research is needed in this area in the future. Therefore, we can conclude that adapting e-learning content to Arabic dyslexia types is beneficial in the case of trained words but we cannot conclude that what is learned from the content can be generalised to other new words. In addition, the young age of the learners has made an obstacle to understanding the effect of content adaptation by measuring their satisfaction with the system in detail. These learners evaluated the system interface which was the same for both conditions and they tended to choose the extreme scores. Here this research ends and is summarised in the next chapter. Suggestions for future work are also highlighted.

Chapter 9

Conclusion

9.1 Introduction

This chapter summarises the whole research of this thesis and provides the answers to the main research questions. The main contributions to the field are presented along with the research limitations. A suggestion of potential resolutions to these issues is also provided for future research.

9.2 Summary of The Work

Reading is one of the main language skills (Mastropavlou and Zakopoulou, 2013) that affects our lives both academically and socially. Some readers have problems with reading and understanding written text and therefore are often excluded socially and educationally (Mastropavlou and Zakopoulou, 2013). These readers may have dyslexia. We focused on this class of people, so we searched the literature to understand them and the different difficulties they face. We found that they face a variety of difficulties, some with reading, writing, spelling and others with behavioural difficulties. Then, we searched deeper into the literature to understand and focus on the dyslexia reading difficulties, because dyslexia is, first, a reading difficulty and reading is our focus.

Reading difficulties of dyslexia are affected by language. Unfortunately, there are few studies that have explored dyslexia in Arabic (Alghabban et al., 2021) (particularly reading difficulties) despite the frequency among native Arabic speakers and Muslims (Mahfoudhi et al., 2011). Therefore, this research focused on Arabic dyslexia.

To deeply understand the reading difficulties of Arabic dyslexia, these difficulties have been categorised into different dyslexia types. The causal classification, reported by (Friedmann and Haddad-Hanna, 2014), has been adopted by this work. They classified Arabic dyslexia into seven Arabic dyslexia types such as letter position dyslexia and vowel letter dyslexia. From these types, we understood that individuals with dyslexia differ in their difficulties.

Next, we searched and analysed the literature for various interventions (technological and non-

technological) that have been proposed to help, in particular, young children with dyslexia. Many of these interventions were not built on theory and treated individuals with dyslexia as a single group with the same difficulties. Further, these interventions lacked well-designed experiments and unreliable evaluations. We have considered these limitations in our work.

Some technological interventions have used e-learning technology (Nagy, 2005). E-learning provides online access to educational materials with flexibility in time and location (Holmes and Gardner, 2006, p. 14). Unfortunately, the same educational material is provided to all learners using the same teaching method while ignoring their individual differences and needs (Maravanyika et al., 2017; Alshammari et al., 2014). So, e-learning in its original form is not suitable for dyslexia because they differ in their difficulties. The solution to this is to "adapt" the e-learning system.

Adapting e-learning systems is tailoring the learning material or content to, for example, learner's characteristics such as the learner's prior knowledge and cognitive traits (Graf et al., 2012; Kamceva and Mitrevski, 2012). Building an adaptive e-learning system requires building three main models: the adaptation model, the learner model and the domain model. The domain model represents the e-learning content, the learner model represents the characteristics of the learner used in the adaptation process and the adaptation model bridges the gap between the learner and the domain models by applying the adaptation process. Building an adaptation model is complex and, in particular, the learner model must rely on reliable tools to extract the learner's characteristics required for adaptation. So, it is important to first understand the effect of adaptation before building the adaptive e-learning system and that is what this research seeks to achieve. To understand the effect of adaptation, it is important to determine (1) the learner's characteristic that will be used in the adaptation process as considering all learner characteristics is difficult and (2) the skill that will be used to study the impact of adaptation on it. There is a set of learner's characteristics that can be addressed and used as a source of adaptation and a variety of skills that can be improved.

Because the target population of this research is learners with Arabic dyslexia, it was appropriate to consider their Arabic dyslexia types to be the chosen learner's characteristic used in the adaptation process. These types are reading difficulties categorised according to the affected component of the dual-route model for single-word reading (Friedmann and Haddad-Hanna, 2014). Since these Arabic dyslexia types represent reading difficulties, improving the reading skill was targeted. To measure the improvement of the learner's reading skill, learning gain was calculated. To improve the reading, the learning process must be effective. For this purpose, another metric was measured in this research; learner satisfaction. Learner satisfaction plays an essential role in the learning process and therefore it can be considered an important factor in evaluating the effectiveness of the e-learning system. It can also reflect the learner's motivation and engagement in the learning process

(Alshammari et al., 2015d; Alakkas, 2016). So, the metrics: learning gain and learner satisfaction were calculated to understand the effect of adaptation directly (learning gain) and indirectly (learner satisfaction). As a result, this research aims to understand the impact of adapting the training material to Arabic dyslexia types on learners' reading and satisfaction.

To accomplish this aim, a series of controlled experiments were conducted. Due to practical reasons, each experiment targeted only two (out of seven) Arabic dyslexia types by directing the training material to these types. Therefore, a dyslexia diagnostic test was designed and reviewed by special education teachers to determine whether a learner has one of the target Arabic dyslexia types or other non-target types. Learners who were diagnosed with one of the target Arabic dyslexia types became participants in the experiment while others were excluded.

The first experiment originally targeted vowel letter dyslexia and letter position dyslexia because they are the most frequent types as reported in (Friedmann and Haddad-Hanna, 2014). However, letter position dyslexia did not appear among the sample of learners with Arabic dyslexia in Riyadh. So, we searched among these learners for another common reading mistake by analysing their mistakes in their dyslexia diagnostic test. A common mistake found is mixing between the phonemes of the three essential short vowels (fat-ha "/a/", kasra "/i/" and dammah "/u/"), ـَ ، ـِ ، ـُ within a word and named as short vowel dyslexia. Therefore, the first two experiments targeted vowel letter dyslexia and short vowel dyslexia where the training material matched vowel letter dyslexia in Experiment One and matched short vowel dyslexia in Experiment Two. These two experiments were conducted as pilot studies in order to (1) understand the effect of matching the training material to one of the Arabic dyslexia types on their reading performance and satisfaction and (2) validate the developed system and tools. The findings of these experiments showed that the reading of the learners with Arabic vowel letter dyslexia and short vowel dyslexia improved similarly and all learners were highly satisfied with the system. Unfortunately, no significant differences were found between the groups in these experiments (see Table 9.1).

Previous experiments were built based on our understanding of dyslexia from the literature point of view. However, after conducting these experiments, we noticed that the literature and practice were inconsistent. So, we thought we need to understand the dyslexia difficulties in practice from the perspective of experts, who are special education teachers and then combine our understanding from the two perspectives (literature and practice) together to refine our approach and conduct the final experiment.

Therefore, a questionnaire was designed and published to special education teachers primarily to find another common Arabic dyslexia reading problem among learners with Arabic dyslexia that is identified as an Arabic dyslexia type (Friedmann and Haddad-Hanna, 2014). Visual dyslexia was

Table 9.1: Overview of Experiments One and Two

Criteria	Experiment One	Experiment Two
Hypotheses	• Matching training material to learners with vowel letter dyslexia (short vowel dyslexia) achieves significantly greater learning gain compared to learners with short vowel dyslexia (vowel letter dyslexia). • Matching training material to learners with vowel letter dyslexia (short vowel dyslexia) achieves significantly greater learner satisfaction compared to learners with short vowel dyslexia (vowel letter dyslexia).	
Arabic Dyslexia Types	Vowel letter dyslexia and short vowel dyslexia	
Academic Level	4^{th} grade - 6^{th} grade	2^{nd} grade - 6^{th} grade
Experimental Design	Matched/mismatched design	
Experiment Location	Hybrid (In person "Riyadh city"+ Online "COVID-19")	
Main Findings	• Mismatched group improved better in learning gain than the matched group. • Both groups were highly satisfied with the system. • Majority of learners were happy and engaged as they learned.	

found and thus the final and main experiment targeted vowel letter dyslexia and visual dyslexia taking into account lessons learned from the first two experiments. In this experiment, the training material was adapted to the learner's Arabic dyslexia type. The results of this experiment were promising as the reading of learners, who experienced training material adapted to their Arabic dyslexia type, improved significantly in the case of trained words. More details about these experiments are presented in the next section (see Table 9.2).

During this research, the world suffered from the Coronavirus pandemic, which positively and negatively affected the experiments. The positive effect was that the experiment was conducted remotely without being restricted to the school's location and schedule. The experiment was conducted on weekdays and weekends, day and night. The negative effect was that the observational process was negatively affected since the experimenter must be available when the learner interacts with the system to observe their behaviour. However, some learners had poor Internet connections and this reduced the quality of the video connection (lens of observation).

9.3 Research Questions Re-visited

This thesis tried to address this main question:

Q: Does adaptation based on the characteristics of learners with dyslexia improve their skills?

Table 9.2: Overview of Experiment Three

Criteria	Experiment Three
Hypotheses	• Adapting training material to learners' Arabic dyslexia type achieves significantly greater learning gain compared to non-adapted material. • Adapting training material to learners' Arabic dyslexia type achieves significantly greater learning gain of seen words compared to non-adapted material. • Adapting training material to learners' Arabic dyslexia type achieves significantly greater learning gain of unseen words compared to non-adapted material. • Adapting training material to learners' Arabic dyslexia type achieves significantly greater learner satisfaction compared to non-adapted material.
Arabic Dyslexia Types	Vowel letter dyslexia and visual dyslexia
Academic Level	2^{nd} grade - 6^{th} grade
Experimental Design	Adaptive/non-adaptive design
Experiment Location	Online "COVID-19"
Main Findings	• Adaptive group improved better in learning gain than the non-adaptive group. • Both groups were highly satisfied with the system. • Majority of learners were happy and engaged as they learned.

However, this question is very broad and covers many aspects that this research cannot address in the time available and for other practical reasons. So, we have identified the learner's characteristic and skill that will be addressed. As detailed in the previous section, Arabic dyslexia type (learner characteristic) and reading skill were selected. Further, learning gain and learner satisfaction were the metrics in this research.

Now, the previous main question was narrowed down into two smaller ones:

Q1: Is there a significant difference in learning gain when adapting training material of an e-learning system to Arabic dyslexia types compared to the non-adapted version?

Q2: Is there a significant difference in learner satisfaction when adapting training material of an e-learning system to Arabic dyslexia types compared to the non-adapted version?

To answer these two questions, we need to understand the impact of adapting training material to Arabic dyslexia types on the learner's reading and satisfaction. To do so, three controlled experiments were conducted with two Arabic dyslexia types. The first two experiments targeted

vowel letter dyslexia and short vowel dyslexia whereas the third experiment targeted vowel letter dyslexia and visual dyslexia.

In each experiment, the Arabic dyslexia type of each learner was determined using the dyslexia diagnostic test followed by taking their demographic information from their special education teachers and obtaining their initial reading level via the pre-test. After that, the learners were divided into two groups (control and experimental) that were balanced in terms of number of learners, Arabic dyslexia type, age, and initial reading level. The control group in the first experiment included learners with short vowel dyslexia, while the experimental group included learners with vowel letter dyslexia. Both groups used the same version of the system which provided training material directed to vowel letter dyslexia. The second experiment complemented the first experiment. The control group included learners with vowel letter dyslexia, while the experimental group included learners with short vowel dyslexia. Again, both groups used the same version of the system that, at this time, provided training material directed to short vowel dyslexia. In the third experiment, both groups included learners with vowel letter dyslexia and visual dyslexia. The control group used the non-adaptive version of the system (general non-adapted training material) whereas the experimental group used the adaptive version (training material adapted to Arabic dyslexia type). After completing these steps, each learner used the e-learning system in eight experimental sessions in the presence of the experimenter either in person or online. At the end of the last experimental session, the learner completed a post-test and filled out the learner satisfaction questionnaire. During the whole experiment, the experimenter observed each learner and took notes about their fun and behaviour and the usability of the system. The learning gain was calculated using the pre- and post-tests scores to measure the reading improvement of each learner.

The results of the first two experiments showed improvement in the learner's reading and they were highly satisfied with the system regardless of their Arabic dyslexia type. But, there were no statistically significant differences in reading improvement and satisfaction between the control and experimental groups.

The results of the third experiment were promising in terms of the reading improvement of learners with Arabic dyslexia. The pre- and post-tests of this experiment included both seen and unseen words, where the seen words are used in the system while the unseen words are not. Therefore, the learning gain of the seen and unseen words were calculated. We found that reading improved significantly better when the training material was adapted to the learner's Arabic dyslexia type. However, this is true for the seen words not for the unseen ones, indicating that what has been learned cannot be generalised to other contexts, which in our case are unseen words. Like the other two experiments, learners were highly satisfied with the system regardless of their Arabic dyslexia

type. This convergence of the learner satisfaction with the training material is likely due to the young age of the learners as they seem to have been unaware of the suitability of the content to them and they have been exposed to the same system's interface and facilities. From this point of view, we conclude that measuring learner satisfaction in detail did not add any valuable results to the learner satisfaction results of the first two experiments. Therefore, it is best to measure learner satisfaction for young learners only by taking their opinions of the system, as was the case in the first two experiments.

Going back to the aim of the research:

"Understanding the impact of adapting the training material to Arabic dyslexia types on learners' reading, satisfaction and behaviour"

We can conclude that adapting the training material to learner's Arabic dyslexia type had a positive impact on their reading. However, we cannot conclude that what the learners have learned can be applied to other words with similar features. Further, the young age of learners tended to evaluate the system interface rather than the training material and to choose the extreme learner satisfaction scores. Therefore, learner satisfaction, in our case, was unable to evaluate the effect of adaptation. Finally, the learners were happy and engaged as they learned and they followed some good practices to improve their learning.

9.4 Summary of Research Contributions

The contributions of this research were discussed in Section 1.5.

- Analysing the literature on Arabic dyslexia and the current e-learning systems to support such individuals to understand dyslexia and identify the weaknesses and limitations of these systems.
- Designing a controlled experiment to evaluate the effect of adaptation to Arabic dyslexia types on learners' learning gain, satisfaction and behaviour which in turn built an understanding of the effect of adaptation on learners with dyslexia.
- Designing a dyslexia diagnostic test (reading test) to determine the learner's Arabic dyslexia type (vowel letter dyslexia, visual dyslexia, both or another Arabic dyslexia type) (Appendix B).
- Supporting the satisfaction in e-learning questionnaire (Siritongthaworn and Krairit, 2006) with a Smileyometer instead of using the original 5-point Likert scale to use the questionnaire with children (Appendix E).

- Discovering a new common Arabic dyslexia reading difficulty among learners with Arabic dyslexia in Saudi primary schools. This is mixing between phonemes of the three essential short vowels (fat-ha /a/, kasra /i/ and dammah /u/), أَ ، إِ ، أُ within a word during reading aloud. This, in turn, may lead to reading another known word such as reading the word "lo'ab" which means "toys" as "la'eb" which means "played".
- Building an understanding of dyslexia from practice and what teachers believe works well for them by identifying important user attributes (e.g. dyslexia type, motivation, attention), successful teaching strategies, important interaction issues and important metrics when evaluating e-learning systems.
- Informing the design of adaptive systems for teaching learners with dyslexia: by determining the features that should be represented in the learner model and then determining the appropriate adaptation strategies.

A number of papers relating to both areas have been published:

- Chapter 5 "Quantitative Results" - **Al-Dawsari, H.**, & Hendley, R. (2021). The Effect of Matching Learning Material to Learners' Dyslexia Type on Reading Performance, In *Advances in Software Engineering, Education, and e-Learning*, p. 837-845. Springer.
- Chapter 5 "Qualitative Results" - Al-Ghabban, W., **Al-Dawsari, H.**, & Hendley, R. (2021). Understanding the Impact on Learners' Reading Performance and Behaviour of Matching E-Learning Material to Dyslexia Type and Reading Skill Level, In *International Conference on Human-Computer Interaction*, p. 135-154. Springer.
- Chapter 6 - **Al-Dawsari, H.**, & Hendley, R. (2022). The Impact of Matching E-Training Material To Dyslexia Type On Reading Performance and Learner Satisfaction & Behaviour. In *35th International BCS Human-Computer Interaction conference.* In Press.
- Chapter 7 - **Al-Dawsari, H.**, & Hendley, R. (2022). Understanding the Needs of Arab Learners with Dyslexia for Adaptive Systems. In *35th International BCS Human-Computer Interaction conference.* In Press.

9.5 Limitations and Future Work

This research has some limitations that should be addressed in future work. The majority of learners who participated in the experiments in this research were female. It is well known that boys and girls differ in their learning. So, re-running the experiments with boys is necessary to study the ability to generalise the training material to boys.

The training materials in this work were intended for primary school-age learners. Thus, this content may not be appropriate for older learners and therefore, the training material must be redesigned to suit their age.

This research targeted the Arabic language. There are other languages either in the same Semitic family or in other families such as European languages. Therefore, in the future, such languages can be considered by redesigning training materials to target these languages.

The reading domain was the focus of this research whereas other domains, such as mathematics, can be studied in the future.

In all experiments, the reading improvement was evaluated in the short term by conducting the post-test directly after completing all the experimental sessions. Therefore, it is impossible to guarantee that the positive effect will be maintained for the longer-term. This leaves future studies to consider the long-term by conducting the same post-test after at least two weeks of completing the experimental sessions.

One of the metrics used in the first two experiments was to examine the difference in learning gain between the two conditions. These experiments included a repetition feature where the learner could not unlock the next activity until they had succeeded in the current one. Some learners in both conditions could not complete all activities within the eight experimental sessions. This affected the post-test score of these learners. Therefore, future work should address this by, for instance, conducting the post-test after completing all activities regardless of the number of sessions held.

Further, the learners were taking conventional lessons while the experiments were being conducted which may have affected the learning gain score of the learner. So, future studies may consider re-running the experiment during the holidays to accurately study the effect of adaptation without any learning effect that could come from these conventional lessons.

Learning gain of reading improvement and learner satisfaction were the main metrics used in this research. However, other metrics can be used in future studies such as reading speed, reading fluency, reading comprehension and spelling improvement. For instance, if the spelling improvement was addressed, then the training material should train the learners on the spelling skill and spelling pre- and post-tests should be designed and used to measure the learning gain of spelling improvement.

Personalising the content of the e-learning system is a challenging task. There are different Arabic dyslexia types that were not addressed here. Therefore, we suggest designing further experiments with other Arabic dyslexia types such as deep dyslexia and attentional dyslexia. Further, dyslexia is not binary as many learners can have the same Arabic dyslexia type with different levels of severity.

However, this research did not address that. Thus, we suggest considering the degree of an Arabic dyslexia type in future studies by providing more reading activities to learners with a high degree of severity than for learners with a low degree in a particular dyslexia type and then studying the adaptation effect. In addition, a learner with dyslexia may have more than one Arabic dyslexia type which future studies should consider. In this case, we suggest providing reading activities that fit these types.

Moreover, the Arabic dyslexia types used in this research are reading difficulties faced by learners with Arabic dyslexia. However, there are also non-reading difficulties that these learners may encounter such as writing and spelling difficulties. Addressing these difficulties in future studies is essential. In the case of spelling, for example, the content of the e-learning system can ask the learner to order a list of letters to make up the spoken word where this word is chosen based on the learner's common spelling mistakes.

Arabic dyslexia type was the learner's characteristic used in the adaptation process to tailor the training material of the system because it reflects the dyslexia reading symptoms. However, other learners' characteristics, beyond the dyslexia symptoms, can be used in the adaptation process such as the learners' affective state which, based on the results discussed in Chapter 7, can be considered an important characteristic for keeping the learner motivated and thus gaining further learning. For instance, the system can present the content in a different way once the learner becomes bored to keep them motivated. A learner's grade can also be addressed. For instance, the learner can be trained on content extracted from their grade's curriculum which will be beneficial in keeping the learner at the same level as their classmates and reduce their boredom by not offering them reading content that they are familiar with or too difficult for them.

More than one learner characteristic can be considered in future research. For example, if the learner's grade and dyslexia type are combined, then the content of the e-learning system will be chosen from the learner's grade curriculum that suits their type.

The system was directed to web users regardless of their devices. Different devices have different screen presentations which affect the clarity of the courses if not considered. For instance, presenting a course on a laptop screen is different from presenting it on a mobile screen. However, the mobility of the courses where the learners can access the lessons from any connected device was not considered. Thus, we suggest redesigning the experiments using mobile learning on which the screen presentation is adjusted on any mobile or tablet screen.

In the last experiment, the number of exercises in each activity was fixed and the learner was able to unlock the next activity regardless of their score. Thus, we suggest adjusting the number of exercises based on the learner score in future research. Increasing the number of exercises in a

particular activity once the learner gets a bad score or decreasing it once they get a good one. This will leave the learner spending more time on unmastered activities rather than wasting their time on the ones they have already mastered.

The dyslexia diagnostic test used in all experiments was in an offline format. The learner's reading errors were analysed manually in order to determine the Arabic dyslexia type of the learner which in turn fed into the learner model manually. Therefore, we suggest that future studies design an online format of the test and embed it with the adaptive system where the Arabic dyslexia type is determined automatically and then also fed automatically into the learner model which is then used to provide the learner with the appropriate content. Such a test would require analysing the learner's reading and comparing it with the original words of the test in order to find out (if any) the learner's errors which are then mapped to dyslexia reading symptoms and then dyslexia types.

Finally, as a consequence of the Coronavirus pandemic, experiments were conducted remotely which negatively affected the observational process. Thus, future studies may consider re-running the experiments in person to accurately observe learners. Also, different results can be achieved in learning gain and learner satisfaction than in our experiments.

9.6 Summary

Reading is an important language skill for all individuals. However, individuals with dyslexia mainly face difficulties with their reading. Because everyone is different, learners with dyslexia are also different and, therefore, their reading difficulties are different. Some migrate letters within a word while others misunderstand what is written. So, their individual differences should be considered to provide appropriate support. From this point of view, this research considered Arabic dyslexia types that reflect the reading difficulties of learners with Arabic dyslexia and then aimed to understand the impact of adapting the training material to Arabic dyslexia types on the learners' learning gain, satisfaction and behaviour. Three controlled experiments were conducted for this purpose and showed promising results in this field.

Adapting e-learning systems to Arabic dyslexia types is still new and has been considered in a few studies. This research demonstrated the effectiveness of adapting the content of the e-learning systems to learners' Arabic dyslexia types, as only two Arabic dyslexia types were focused. Due to practical reasons such as time constraints, this research can be considered as a starting point for further investigation that includes other Arabic dyslexia types and builds a dynamic adaptive Arabic dyslexia model to improve learners' reading.

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Appendix A

Consent Form (English Version)

Dear parent or guardian,
Thank you for your interest in allowing your child to participate in our study. The aim of this study is to improve one of the reading skills of your child by offering a range of exercises using different techniques through a training system. We will observe the child's reading improvement in both techniques to decide which one suits him/her based on his/her dyslexic type through testing his/her reading skill before and after applying the training system.

Before starting, we require that you carefully read the following information about this study and indicate whether you agree or disagree to enrol your child.

1. **Introduction:**
   Your child will be enrolled in a study on human computer interaction at the University of Birmingham's School of Computer Science. We are seeking your permission as your child is younger than 18 years, and we will ask her to complete a dyslexic diagnostic test and use our training system. For your child to do so, we need your permission.

2. **The steps of the study your child will participate in:**
   - Your child will take a dyslexic diagnostic test to identify the dyslexia type he/she suffers from.
   - His/her teacher will register him/her in the system by providing some personal information, such as age, gender, etc.
   - Your child will complete a pre-test form to assess one of his/her existing reading skill before using our training system.
   - Your child will use our training system during school sessions to train him/her on previously studied reading skills.
   - If your child completes the study, then he/she will take:
     - A post-test to assess his/her reading skill after using our training system.
     - A usability questionnaire to measure his/her confidence in using our system.
   - A video will be recorded for your child or some pictures will be taken of him/her during the study for the study purposes if you agree.

3. **Withdraw from the Study:**
   Your child is free to withdraw from the study at any time. You can contact at least one of the researchers within 8 weeks of their commencing the study (***using one of the email addresses below***).

4. **Time required:**
   The training will require using reading sessions that are given during school's day for three to four weeks, and your child may withdraw from the study at any time he/she wants.

5. **Benefits to Participants:**
   Your child will gain free reading training in a previously taught reading skill to improve his/her reading weaknesses in that skill.

6. **Risks to Participants:**
   - We will only collect information about your child, including their results from the diagnostic test, pre and post-tests and satisfaction questionnaire.
   - All the collected information will be anonymous and safely secured and encrypted before being stored in a database.
   - Only the researchers will be able to access the database using unique student identifiers (***IDs***) associated with each child participates in the study.

Participation in this study is voluntary (***optional***), and your child may withdraw at any time he/she wants. Please read the preceding information carefully, and then indicate below whether you agree or disagree to allow your child to: participate in the study, record a video and/or take some pictures of him/her during his/her participation.

Participating in the study:

- o I agree to let my child to participate in the study.
- o I disagree to let my child to participate in the study.

Recording a video during the study:

- o I agree to the recording of a video of my child during the study.
- o I disagree to the recording of a video of my child during the study.

Taking some pictures during the study:

- o I agree to the taking of some pictures of my child during the study.
- o I disagree to the taking of some pictures of my child during the study.

For further information, please do not hesitate to contact us by email:
[redacted] or [redacted]

If you would like to see the final published results of this study you should contact one of the researchers at the above addresses.

Name of parent / guardian: ……
Date: ……...
Signature: ……...

Consent Form (Arabic Version)

عزيزي ولي الأمر
نشكرك على السماح لطفلك/طفلتك بالمشاركة في دراستنا هذه، والتي تهدف إلى تحسين إحدى مهارات القراءة لطفلك/طفلتك عن طريق تقديم مجموعة من التمارين التدريبية باستخدام تقنيات مختلفة عبر برنامج تدريبي, والتي ستعكس مدى تحسن قراءة الطفل بتلك التقنيات، للوقوف على الأنسب منها لطفلك/طفلتك، بناء على مقارنة قراءته أو قراءتها قبل وبعد تطبيق البرنامج التدريبي المقترح في دراستنا.

بداية نرغب إليك قراءة المعلومات التالية بعناية حول دراستنا هذه، والاشارة إلى الموافقة على مشاركة طفلك/طفلتك في الدراسة من عدمها، شاكرين لكم حسن تعاونكم.

1. المقدمة:

سيتم تسجيل طفلك/طفلتك في دراسة حول التفاعل بين الإنسان والحاسب الآلي، والتي تقوم بها طالبة الدكتوراه/ هديل بنت محمد الدوسري (المبتعثة من جامعة الأميرة نورة بنت عبد الرحمن)) في قسم علوم الحاسب بجامعة برمنجهام بالمملكة المتحدة، والتي تتطلب موافقتك مشكورا، على انضمام طفلك/طفلتك لهذه الدراسة والذي يقل عمره عن 18 عاما، لنتمكن من إشراكه/ ها في اختبار تشخيص عُسر القراءة، واستخدام البرنامج التدريبي الخاص بهذه الدراسة.

2. خطوات الدراسة التي سيشارك فيها طفلك/طفلتك:

- سيخضع طفلك/طفلتك لاختبار تشخيص عُسر القراءة لتحديد نوع ذلك العُسر.
- سيتولى معلمه أو معلمتها بتسجيله أو تسجيلها في البرنامج التدريبي من خلال توفير بعض البيانات الشخصية مثل العمر والجنس وما إلى ذلك.
- سيقوم طفلك/طفلتك بتقديم اختبار قبلي لتقييم إحدى مهارات القراءة لديه قبل استخدام البرنامج التدريبي الخاص بالدراسة.
- سيقوم طفلك/طفلتك باستخدام البرنامج التدريبي الخاص بالدراسة، خلال جلسات المدرسة لتدريبه على مهارات القراءة التي سبق دراستها.
- إذا أكمل طفلك/طفلتك الدراسة فسيخضع لما يلي:
  - اختبار بعدي لتقييم مهارات القراءة، بعد استخدامه للبرنامج التدريبي الخاص بدراستنا.
  - استبيان قابلية الاستخدام لقياس ثقته/ ثقتها في استخدام برنامجنا التدريبي.
- بعد موافقتكم سيتم التقاط صور، أو تسجيل مقطع فيديو لطفلك/لطفلتك أثناء إجراء الدراسة لغرض الدراسة فقط.

3. الانسحاب من الدراسة:

لطفلك/لطفلتك كامل الحرية في الانسحاب من الدراسة في أي وقت شاء، ويمكنك الاتصال للإفادة عن عدم رغبته/رغبتها في الاستمرار في الدراسة، بأحد الباحثين في غضون 8 أسابيع من بدء الدراسة (عبر أحد عناوين البريد الإلكتروني أدناه).

4. الوقت المطلوب للدراسة

سيتم تدريب طفلك/طفلتك عبر جلسات القراءة خلال اليوم المدرسي لمدة تتراوح بين ثلاثة إلى أربعة أسابيع، ولطفلك/لطفلتك الحرية التامة في الانسحاب من الدراسة في أي وقت شاء.

5. فوائد للمشاركين

سيحصل طفلك/طفلتك على تدريب مجاني في مهارة القراءة التي سبق دراستها لتحسين نقاط ضعف القراءة لديه في تلك المهارة.

6. التزامات الباحث و الفريق المشارك في الدراسة

- ستقوم الدراسة فقط بجمع معلومات حول طفلك/طفلتك، بما في ذلك نتائج كلا من اختبار التشخيص والاختبار القبلي والبعدي، واستبيان الرضا عن البرنامج التدريبي.
- جميع المعلومات عن طفلك/طفلتك لغرض الدراسة فقط وستكون مجهولة المصدر، ومشفرة قبل تخزينها في قاعدة البيانات الخاصة بالدراسة.
- سيقتصر الدخول إلى قاعدة البيانات على الباحثة (طالبة الدراسات العليا) والباحثين المشاركين في الدراسة فقط، عبر معرفات الطلاب/الطالبات المستهدفين بالدراسة (IDs).

المشاركة في هذه الدراسة طوعي (اختياري) ويمكن لطفلك/لطفلتك الانسحاب من الدراسة في أي وقت شاء. الرجاء قراءة المعلومات سالفة الذكر، آملين موافاتنا بالموافقة أو عدم الموافقة لمشاركة طفلك/طفلتك في كلا من: الدراسة، تسجيل مقطع فيديو و/ أو التقاط صورة لطفلك/لطفلتك أثناء مشاركته/ مشاركتها في الدراسة.

المشاركة في الدراسة

- أوفق على مشاركة طفلي / طفلتي في الدراسة.
- لا أوفق على مشاركة طفلي / طفلتي في الدراسة.

تسجيل فيديو أثناء الدراسة

- أوفق على تسجيل مقطع فيديو لطفلي / طفلتي أثناء الدراسة.
- لا أوفق على تسجيل مقطع فيديو لطفلي / طفلتي أثناء الدراسة.

التقاط بعض الصور أثناء الدراسة

- أوفق على التقاط بعض الصور لطفلي / طفلتي أثناء الدراسة
- لا أوفق على التقاط بعض الصور لطفلي / طفلتي أثناء الدراسة

لمزيد من المعلومات، يرجى عدم التردد، في الاتصال بنا عبر البريد الإلكتروني:

إذا كن ترغب في الاطلاع على النتائج النهائية المنشورة للدراسة، بإمكانكم الاتصال بأحد الباحثين على البريد الإلكتروني أعلاه

اسم ولي الأمر: .....

التاريخ: .....

التوقيع: .....

Appendix B

Dyslexia Diagnostic Test of Experiment 3

القسم الأول/ قراءة الكلمات قراءة صحيحة بدون اضافة او حذف او ابدال احرفها بأحرف أخرى.

Section one/ Read the words correctly without adding, deleting, or replacing their letters with other letters (VSD).

أقرأ ما يلي:

خَوْفَ	قَمَرُ	ضِفْدَعَ	بَلَلَ	يَمْتَـدُّ
شَمْسِ	سُوَرَ	يَبْذُرُ	حَمَلَ	أَمَلُ

القسم الثاني/ قراءة الكلمات مع حركاتها الطويلة والقصيرة.

Section two/ Read words with their long and short vowels (VD).

أقرأ ما يلي:

كَبُرَ	وُلِدَ	عَمِلَ	كُرَةُ	صُقُورْ
طَالِبْ	طُيُورْ	جَلِيسُ	قَلْبِي	سَمِعَ

Appendix C

Structured Interview

Section 1: Demographic Information — الجزء الأول: المعلومات الشخصية

1. Name (***Optional***): ..... الاسم (اختياري)
2. Degree: ..... الدرجة العلمية
3. Major: ..... التخصص
4. Career: ..... المهنة
5. Experience (***in Years***): ..... الخبرة (سنوات)
6. School: ..... المدرسة

Can I record the interview? (Yes / No) ***هل بالإمكان تسجيل اللقاء (نعم / لا)***

Section 2: Student — الجزء الثاني: الطالب/ الطالبة

✓ **ماهي المشاكل التي يعاني منها الطالب/ـة في القراءة؟ وماهي الطريقة المتبعة لتدريسه/ها لتتناسب مع مشكلته/ها؟**

✓ What are the problems that the student face in reading? What is the method used to teach the student to suit their problems?

1. صعوبة التعرف على الأحرف.
2. عدم القدرة على قراءة الأحرف مجتمعة لتكوين الكلمة.
3. قراءة اسم الحرف عوضا عن صوته.
4. تبديل أماكن أحرف الكلمة الواحدة (شقلبة الكلمة).
5. تبديل أماكن الأحرف بين كلمتين متجاورتين.
6. إضافة حرف/ حذف حرف/ استبدال حرف بحرف آخر في أي مكان بالكلمة.
7. إضافة حرف/ حذف حرف/ استبدال حرف بحرف آخر في أحد طرفي الكلمة.
8. إضافة حرف مد/ حذف حرف مد/ استبدال حرف مد بحرف مد آخر في أي مكان بالكلمة.
9. الخلط بين الحركات القصيرة (أي قراءة الكلمات بغض النظر عن حركاتها القصيرة).
10. قراءة الكلمات بمعناها.
11. قراءة الكلمات الشاذة والتي تحتوي على: واو الجماعة (اصطفوا), الشدة, تنوين الفتح, الهمزة, التاء المربوطة والألف المقصورة.
12. صعوبة في الفهم القرائي.
13. قراءة بطيئة.
14. قراءة عشوائية.
15. استبدال الكلمة الهدف بكلمة مشابهة لها.
16. أخرى؟

1. Difficulties in identifying letters.
2. Inability to combine letters to form the word.
3. Reading the name of the letter instead of its phoneme.
4. Migrating the letters within the word.
5. Migrating the letters between two adjacent words.
6. Adding / deleting / substituting letters within a word.
7. Adding / deleting / substituting letters at one end of a word.
8. Adding / deleting / substituting long vowels within a word.
9. Mixing between short vowels only.
10. Reading the word by its meaning.
11. Reading irregular words which contain: phoneme WA: Shaddah, Tanween fatha, Hamza, Taa Marbootah and alef maqsoorah.

12. Difficulties in reading comprehension.
13. Slow reading.
14. Random reading.
15. Replacing the target word with a word similar to it.
16. Other?

طريقة التدريس Teaching Method	مشاكل في القراءة Reading Problems															رقم الطالب Student ID
	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

✓ هل أنت موافق/ـة على نتيجة الاختبار التشخيصي للطالب/ـة؟ لماذا؟

✓ Do you agree with the student's diagnostic test result? Why?

السبب Reason	نعم / لا Yes/No	رقم الطالب Student ID

✓ هل يتحدث الطالب/ـة إحدى اللهجات العربية؟

✓ Does the student speak an Arabic dialect?

إذا كانت الإجابة بنعم فما هي تلك اللهجة؟ If yes, what is that dialect?	نعم / لا Yes/No	رقم الطالب Student ID

✓ هل تعتقد أن لهجة الطالب/ـة أثرت على طريقة قراءته/ها للكلمة؟ لماذا؟

✓ Do you think the student's dialect affect their reading? Why?

السبب Reason	نعم / لا Yes/No	رقم الطالب Student ID

✓ **أي من أنواع الذاكرة التالية التي يفضل الطالب/ـة استخدامها أثناء جلسات التدريس (يمكنك اختيار أكثر من واحد)**

✓ Which of the following types of memory do the student prefer to use during teaching sessions (you can choose more than one).

الذاكرة اللفظية Verbal Memory	الذاكرة البصرية Visual Memory	الذاكرة السمعية Auditory Memory	رقم الطالب Student ID

✓ **هل يعاني الطالب /ـة من مشكلة واحدة أو أكثر من المشكلات التالية (يمكنك اختيار أكثر من مشكلة):**

✓ Does the student face one or more of the following problems? (You can choose more than one).

1. مشاكل في تذكر الأشياء، مثل تسلسل الأحرف الهجائية، أو الأشهر والأرقام، والأسماء وغيرها.
2. مشاكل في التركيز.
3. مشاكل في الرؤية.
4. مشاكل في التمييز بين الاتجاهات.
5. الانزعاج من وهج الأضواء الساطعة والخلفيات ذات اللون الأبيض.
6. أخرى؟

1. Problems with remembering such as; sequences (***e.g. alphabets, months, numbers***), names, etc.
2. Problems with concentration and focus.
3. Problems with vision.
4. Problems in differentiating between directions.
5. Being upset due to sensitivity to the glare of bright lights and backgrounds with white colour.
6. Other?

6	5	4	3	2	1	رقم الطالب Student ID

✓ **هل الطالب/ـة جيد في واحد أو أكثر مما يلي (يمكنك اختيار أكثر من واحد).**

✓ Is the student good in one or more of the following (you can choose more than one).

أخرى؟ Other?	تصور قوي Strong visualization	حل المشكلات Problem solving	الوعي المكاني Spatial awareness	الإبداع Creativity	مهارات القيادة Leadership skills	رقم الطالب Student ID

✓ **هل يعاني الطالب/ـة من واحدة أو أكثر من الصعوبات أو الاضطرابات التالية (يمكنك اختيار أكثر من واحدة):**

✓ Does the student face one or more of the following difficulties or disorders? (You can choose more than one).

1. صعوبة في اللغة الشفوية (الشفهية).
2. صعوبة في اللغة المكتوبة.
3. صعوبة في التنظيم
4. عُسر الحساب (صعوبة في الرياضيات).
5. عُسر في الكتابة (صعوبة في الكتابة اليدوية).
6. صعوبة في الانتباه (اضطراب نقص الانتباه وفرط الحركة ADHD).
7. خلل الأداء (صعوبات في المهارات الحركية).
8. مشاكل في الذاكرة (الذاكرة العاملة، الذاكرة قصيرة المدى، أو الذاكرة طويلة المدى).
9. اضطرابات عاطفية وسلوكية (مثل ضعف الثقة في النفس، أو الاكتئاب).
10. أخرى؟

1. Difficulty with oral language
2. Difficulty with written language
3. Difficulty with organization.
4. Dyscalculia (***Difficulty with math***).
5. Dysgraphia (***Difficulty with handwriting***).
6. ADHD (***Difficulty with attention (Attention Deficit Hyperactivity Disorder)***).
7. Dyspraxia (***Difficulty with motor skill***).
8. Memory problems (***working memory, short-term memory or long-term memory***).
9. Emotional and behaviour disorders (***such as, poor self-esteem, or depression***).
10. Other?

10	9	8	7	6	5	4	3	2	1	رقم الطالب Student ID

✓ **هل تعتقد أن استخدام برنامجا حاسوبيا لتدريب الطالب/ـة على القراءة ستسهم في تحسين مستوى قراءته/ها؟ وضح إجابتك.**

✓ Do you think that using a computer program to train students to read will improve their reading? Explain your answer.

- نعم (Yes).
- لا (No).

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- ✓ **هل تعتقد أن استخدام الألعاب في البرنامج الحاسوبي في تدريب الطالب/ـة على القراءة ستسهم في تحسين مستوى قراءته/ها؟ لماذا.**
- ✓ Do you think that using games in the computer program to train students to read will improve their reading? Why.
  - o نعم (Yes).
  - o لا (No).

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- ✓ **هل تعتقد أن استخدام كلمات تستهدف المشكلة الأساسية التي يعاني منه/ها الطالب/ـة ستحسن قراءته/ها أكثر من استخدام كلمات عشوائية لا تستهدف تلك المشكلة؟ لماذا؟**
- ✓ Do you think that using words targeting the student's problem will improve their reading more than using random words? Why?
  - o نعم (Yes).
  - o لا (No).

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Section 3: Diagnostic Test — الجزء الثالث: الاختبار التشخيصي

- ✓ **هل مشكلة التبديل بين أماكن أحرف الكلمة الواحدة شائعة بين طلاب/طالبات عسر القراءة؟**
- ✓ Is migrating letters within a word common between students with dyslexia?
  - o نعم (Yes).
  - o لا (No).

- ✓ **هل مشكلة الخلط بين الحركات القصيرة والطويلة شائعة بين طلاب/طالبات عسر القراءة؟**
- ✓ Is mixing between short and long vowels common between students with dyslexia?
  - o نعم (Yes).
  - o لا (No).

- ✓ **هل مشكلة الخلط بين الحركات القصيرة فقط شائعة بين طلاب/طالبات عسر القراءة؟**
- ✓ Is mixing between short vowels only common between students with dyslexia?
  - o نعم (Yes).
  - o لا (No).

- ✓ **هل مشكلة إضافة/ حذف/ إبدال حروف داخل الكلمة شائعة بين طلاب/طالبات عسر القراءة؟**
- ✓ Are adding/deleting/substituting letters within a word common between students with dyslexia?
  - o نعم (Yes).
  - o لا (No).

✓ أي الكلمات التالية تساهم في إبراز المشاكل الثلاثة السابقة ولماذا؟

✓ Which of these words contribute to highlighting the previous four problems and why?

الكلمة Word	نوع المشكلة Problem Type				السبب Reason
	التبديل بين أماكن أحرف الكلمة الواحدة Migrating letters within a word	إضافة/ حذف/ إبدال حروف داخل الكلمة Adding/ deleting/ substituting letters within a word	الخلط بين الحركات القصيرة والطويلة Mixing between long and short vowels	الخلط بين الحركات القصيرة فقط Mixing between short vowels Only	
يَعْمَلْ					
قَلْبْ					
جَرَسْ					
يُمْهِلْ					
يَصْنَعْ					
يَكْبِتْ					
يَحْلُمْ					
مَعْمَلْ					
يَسْحَبْ					
نَفْقْ					
كَبُرَ					
وُلِدَ					
عَمِلَ					
كُرَةُ					
صُفُّورْ					
طَالِبْ					
طُيُورْ					
جَلِيسُ					
قَلْبِي					
سَمِعَ					

- ✓ **هل توجد مشاكل أخرى شائعة بين طلاب/طالبات عسر القراءة؟**
- ✓ Are there other problems common between students with dyelxia?
  - نعم (Yes).
  - لا (No).

- ✓ **إذا كانت الإجابة بنعم، فماهي تلك المشاكل؟**
- ✓ If yes, what are these problems?

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……
……
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Appendix D

Pre and Post-Tests of Experiment 3

أقرأ ما يلي:

Read the following:

بِخَمْسِ	مَكْتَبُ	بَدَنُكْ	نَخْلَةُ	مَعْدِنْ
كَاتِبَ	فَقِيرْ	أَقُولُ	قَاضِي	قُرُودَ

Appendix E

Learner Satisfaction

First Name:…… Age:……   Grade:(2, 3, 4, 5, 6) Gender:(Male, Female)
What is your opinion about the system?      Awful Not very good Good Really good Brilliant

Satisfaction in E-learning (English Version)

First Name:.....
Grade:(2,3,4,5,6)

Age:.....
Gender:(Male, Female)

Section	English Version	 Awful	 Not very Good	 Good	 Really Good	 Brilliant
Content	I am satisfied with examples of the real world situation/practice, in the EL part of this course					
	I feel that the content provided in the EL part of this course is sufficient.					
Systems	I am satisfied with the ease-of-use of the EL system					
	I agree that the EL system usually performs well.					
	This EL system makes it easy for me to find the content I need (i.e. course title, additional resources, material, topics, activities, web board discussions etc.)					
Delivery Method	I feel that the presentation of material provided in the EL part of this course is easy to understand					
	I am satisfied with the format (or software application) of material provided in the EL part of this course.					
	I can learn a lot and have fun at the same time with the EL system					
	I am satisfied with the way quizzes, exercises, and additional activities in the EL part of this course improve my learning.					
Overall Satisfaction	Overall, I am satisfied with the EL system					

Satisfaction in E-learning (Arabic Version)

اسم الطالب/ة: العمر:

المرحلة الدراسية: (الثاني، الثالث، الرابع، الخامس، السادس) الجنس: (ذكر ، أنثى

القسم	النسخة العربية	 سيء	 ليس جيد	 جيد	 جيد جدا	 ممتاز
المحتوى	أنا راض عن أمثلة نظام التعليم الإلكتروني (هيا نتعلم) الواقعية					
	أشعر أن المحتوى المقدم في نظام التعليم الإلكتروني (هيا نتعلم) كافٍ.					
الأنظمة	أنا راضٍ عن سهولة استخدام نظام التعليم الإلكتروني (هيا نتعلم).					
	أوافق على أن نظام التعليم الإلكتروني (هيا نتعلم) عادة يعمل بشكل جيد.					
	يسهّل هذا النظام للتعليم الإلكتروني (هيا نتعلم) العثور على المحتوى الذي أحتاجه (مثل عنوان الدرس والموارد الإضافية والمادة العلمية والموضوعات والأنشطة ولوحة ويب للمناقشات وما إلى ذلك).					
طريقة توصيل المعلومة	أشعر أن المواد الموجودة في نظام التعليم الإلكتروني (هيا نتعلم) معروضة بطريقة سهلة الفهم					
	أنا راضٍ عن تنسيق المواد المقدمة في نظام التعليم الإلكتروني (هيا نتعلم).					
	يمكنني أن أتعلم الكثير وأستمتع في نفس الوقت مع نظام التعليم الإلكتروني (هيا نتعلم).					
	أن راض عن الطريقة التي تحسن بها تعلمي من خلال الاختبارات القصيرة والتمارين والأنشطة الإضافية التي يقدمها نظام التعليم الإلكتروني (هيا نتعلم).					
الرضا العام	بشكل عام ، أنا راضٍ عن نظام التعليم الإلكتروني (هيا نتعلم).					

Appendix F

Research Ethics Statement
HCI: Adaptive Learning for Dyslexic Users
Name of PGR student: Mrs Hadeel Al-Dawsari
Principal supervisor: Robert Hendley

Study Details

The study took place at primary schools in Saudi Arabia. The participants were dyslexic primary school students who were aged 9 to 12 years old Arabic native speakers.

Their parents' / guardians' consent was taken with full awareness of the requirements of the study, including the knowledge of exactly what data would be collected.

At the beginning of the study, participants were asked to provide primary information, such as demographic information and completed both, a diagnostic test to identify their dyslexic type and a pre-test to determine their level of reading skill. Diagnostic tests to identify the learning difficulty type were available from the Ministry of Education. The reading exercises used were those available in the Saudi curriculum with input from teachers.

This project explored ways in which to improve the reading skill of an Arabic dyslexic student by offering a range of reading exercises through an adaptive learning system. The exercises were provided to the student using the appropriate techniques for him/her based on his/her dyslexic type.

At the end of the study, the participants were asked to complete both a post-test to identify the level of improvement in their reading skill and a satisfaction questionnaire to measure their confidence in using the developed learning system.

Participant recruitment

After obtaining permission from the Ministry of Education and from the primary school head teachers, the researcher visited participating schools and identified potential students to take part in the research with the assistance of the school staff. The study was undertaken in the child's school during the school reading session with their teacher present.

Each participant was free to withdraw from the study at any time. His/her parents/guardians could withdraw their children from the study by contacting at least one of the researchers before the completion of the study

Data Management

The teacher registered participants in the system by providing their demographic information. Picture and video recordings of the participants using the learning system were captured in order to analyse the participants' behaviour and emotions, with the permission of their parents/guardians.

All data collected from the participants was encrypted and stored in a secured database. Each participant's data was identified with an ID only accessible to the researchers who had access to the database. A secured connection was used to protect all communication to and from the database. Data was retrieved by using the anonymous participant IDs. Participant IDs were saved along with his/her dyslexic type and the results of the pre and post-tests. Data was backed up using the university BEAR service. Data was archived in the university storage facility for ten years.

Research Ethics and Governance Assessment

This project was submitted for research ethics review on the 26.7.2019 and feed-back from the review was provided on the 30.9.19 but a response to the research ethics review was not received.

On the 29.9.22 the Research Ethics Team received notification that this project had been completed and a review of the way in which the study was adapted in line with the feed-back from the research ethics review was undertaken by the Head of Research Governance & Integrity, the Research Ethics Manager and the Co-Chair of the Science, Technology, Engineering and Mathematics Ethics Review Committee to establish if ethical issues were considered sufficiently to allow data to be used and to identify corrective actions that would need to be considered for this project.

There is evidence that ethical issues in relation to the identification of participants, information and consent processes and participant withdrawal were considered. There was consideration for the need of appropriate data management.

Based on this review, it was agreed that the project had considered ethical issues and data from this project can be used for the research. This ethics statement was approved by the Director of Research and Head of College.



Dr Birgit Whitman
Head of Research Governance & Integrity
Research Strategy and Services Division
University of Birmingham

Appendix G

Observed Fun Checklist (English Version)

Learner ID	Issues						
	Engaged	Bored	Happy	Sad	Compliment	Criticism	Other
1							
2							
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Observed Fun Checklist (Arabic Version)

رقم المتعلم	المعايير						
	الاندماج	الملل	الفرح	الحزن	المدح	الذم	أخرى
1							
2							
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Appendix H

Observed Usability Checklist (English Version)

Learner ID	Issues														
	Is sound clear?		Is image clear?		Is text clear?		Choosing correct buttons?		Knowing what is going on?		Not going back?		Knowing what to do?		Other
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	
1															
2															
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Observed Usability Checklist (Arabic Version)

رقم المتعلم	الصوت واضح		الصورة واضحة		النص واضح		اختيار الأزرار الصحيحة		معرفة ماذا يجري		عدم الرجوع إلى الوراء		معرفة المطلوب		أخرى
	نعم	لا	نعم	لا	نعم	لا	نعم	لا	نعم	لا	نعم	لا	نعم	لا	
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Appendix I

Demographic Section Updates

#	Initial Version		Teacher Comments	Requires modification?	Final Version	
	Question	Answers			Question	Answers
1	Are you a special educational teacher?	Yes No	No Comments	No	Same as initial version	
2	What is your academic level?	Bachelor Master PhD Other	No Comments	No	Same as initial version	
3	What is your gender?	Male Female	No Comments	No	Same as initial version	
4	How many years of teaching experience?	Open ended question	No Comments	No	Same as initial version	
5	Which city do you teach in?	Open ended question	No Comments	No	Same as initial version	
6	What is the educational stage you are teaching?	Primary Stage High Stage	No Comments	No	Same as initial version	

7	Which grades do you teach?	1 2 3 4 5 6 7 8 9 10 11 12	No Comments	No	Same as initial version
8	If you have taught before in another city, then please specify?	Yes No	No Comments	No	Same as initial version

Dyslexia Section Updates

#	Initial Version		Teacher Comments	Researcher Comments	Requires modification?	Final Version	
	Question	Answers				Question	Answers
10	During your teaching journey, have you ever encountered any TRUE students with dyslexia?	Yes No	1. All teachers agreed on its clarity. 2. Only one teacher suggested changing "genetic" to "developmental problems".	All teachers did not misunderstand this question, so it will remain unchanged.	Yes	Use "developmental issues" instead of "genetic"	Same as initial version
11	Please choose the most common reading difficulties you have encountered between dyslexic students (you can choose more than one option):	Difficulty 1: Migrating the letters within the word. E.g. reading the word "Ya'mal" as "Ya'lam". Difficulty 2: Mixing short vowels only. E.g. reading the word "kotob" as "katab". Difficulty 3: Mixing between long and short vowels. E.g. reading the word "Katab" as "Kaateb".	1. All teachers agreed on its clarity. 2. One teacher suggested adding a fourth option "ALL" because sometimes a student may suffer from all of these difficulties. 3. One teacher suggested adding another example for migrating letters in Difficulty 1 that result in a nonword because migration may result in a nonword.	1. The question enables the teachers to choose more than one option, so no need for the "ALL" option. They just select all of the options. 2. Adding the "Other" option may be a good suggestion in order not to force the teacher to choose from the available ones in case non of them was appropriate.	Yes	Same as initial version	1. Split Difficulty 1 into 2 options --> Difficulty 1: Migrating the letters within the word that may result in a known word such as reading the word "Ya'mal" as "Ya'lam" and Difficulty 2: Migrating the letters within the word that may result to nonword such as reading "Yahmel" as "Yamhel". 2. Add Option 5: "Other" with a specific text box.

12	Why do you think these are the most common reading difficulties from your perspective?	Open ended question	All teachers agreed on its clarity.	There was a variety of answers. So it will remain an open ended question.	No	Same as initial version	
13	If you have found these reading difficulties between Arab dyslexics, then how strongly do you agree on that their dialect affected their reading?	Strongly Agree Agree Disagree Strongly Disagree	1. 63% of teachers agreed on its clarity. 2. One teacher claimed that the question is not clear because dyslexia is a difficulty due to a malfunction of the brain and there is no relationship between dyslexia and dialects. 3. One teacher commented that a dialect is not considered a difficulty. 4. One teacher did not agree with the word "dialect" and suggested either explaining it, rephrasing the question or writing a note about the way that a dialect might affect the reading.	Based on teachers comment, I suggest to rephrase the question with an explanation about the way that a dialect might affect dyslexics reading.	Yes	"Arabic societies speak different Arabic dialects such as; Najdi dialect, Hijaz dialect, Bedwens dialect, Syrian dialect, etc. Some of these dialects pronounce some Arabic letters differently such as pronouncing Thal as Dal while others mix letters within the word such as pronouncing "Melaqah" as "Maalagah". So, If you have found these reading difficulties among Arab dyslexics, then how strongly do you agree that their dialect affected their reading? "	Same as initial version

14	What is their dialect?	Open ended question	1. 40% of teachers agreed on its clarity. 2. One teacher claimed that the question is not clear. 3. One teacher claimed that the dialect does not differ from the Standard Modern Arabic so she does not think that dialect affects dyslexia. 4. One teacher did not agree on asking a question about dialect. 5. One teacher misunderstood between dialect and the first language in the case of Non-Arab dyslexics. 6. One teacher misunderstood the question by thinking that the question meant the dialect of the mother and not the dyslexic herself.	Based on teachers' comments and their answers: 1. Only one correct answer. 2. 50% wrong answers. 3. 25% mentioned unclear question. It seems that some teachers misunderstood the question. So once the previous question is rephrased then this question will be clear. Note: I do not agree with point 3 of the teachers' comments because there are many dialects where some of them are close to the Standard Modern Arabic while others are far from it.	No	Same as initial version

15	If you have found these reading difficulties between non-Arab dyslexics, then what is their origin?	Open ended question	"1. 50% of teachers agreed on clarity. 2. One teacher claimed that the question is not clear. 3. One teacher suggested rephrasing the question by using the word "nationality" instead of "origin". 4. One teacher misunderstood the question. 5. One teacher claimed that she did not teach non-Saudis. 6. One teacher misunderstood between dialect and the first language in the case of Non-Arab dyslexics."	Based on teachers' comments and their answers: 1. 63% did not teach Non-Arab dyslexics. 2. 1 wrong answer. 3. 1 suggested rephrasing the question. It seems that some teachers misunderstood the question. So it should be rephrased, add examples to some origins and add an extra question checking whether a teacher taught Saudis in nationality but Non-Saudis in origin to be asked this question.	Yes	Add this question before question 15: Some dyslexics are Saudis by nationality but not by their origin. So, some of them came from other Arab countries such as Syria and Egypt while others came from non-Arab countries such as Pakistan and Indonesia. Thus, they might speak their origin language as their first language in instead of Arabic. So Have you taught non-Arab dyslexics (whether their nationality is Saudi or not)?	Yes/No question
						If you have found these reading difficulties between non-Arab dyslexics (whether their nationality is Saudi or not), then what is their origin?	Same as initial version

16	What is their first language?	Open ended question	1. 60% of teachers agreed on its clarity. 2. One teacher claimed that the question is unclear. 3. One teacher suggested deleting the question because the previous one is adequate. 4. One teacher misunderstood between dialect and the first language in the case of Non-Arab dyslexics. 5. One teacher claimed that she did not teach non-Saudis.	Based on teachers' comments and their answers: 1. 2 did not teach Non-Arab dyslexics. 2. 3 wrong answers. 3. 1 suggested rephrasing the question. 4. 1 claimed that the question is unclear. It seems that some teachers misunderstood the question while others did not teach such students. Due to its similarity with the previous question, So I suggest deleting the question and sticking to the previous one.	Yes	Delete this question
17	Have you encountered	Yes No	All teachers agreed on its clarity.	No comments.	No	Same as initial version

18	If Yes, then why do you think it is common in your city schools? (you can choose more than one option).	They were not Arabs in their origin and speak Arabic as their second language.	All teachers agreed on its clarity.	Adding the "Other" option may be a good suggestion in order not to force the teacher to choose from the available ones in case non of them was appropriate.	Yes	Same as initial version	Add the "Other" option with a specify text box.
		They were taught using inappropriate teaching strategies.					
		They were originally Arab who mix letters positions in their dialect which affected their reading at school (e.g. Arabs from Syria region).					
19	If you have other reasons, please list below.	Open ended question	All teachers agreed on its clarity.	There was a variety of answers. So it will remain an open-ended question.	No	Same as initial version	

20	If No, then why do you think it is rare in your city? (you can choose more than one option).	They were taught using appropriate teaching strategies such as Qa'eda Al-Nawraniah.	"1. All teachers agreed on its clarity. 2. One teacher suggested removing " Qa'eda Al-Nawraniah" from the first option because it caused reading problems for some dyslexics."	1. One teacher suggested removing " Qa'eda Al-Nawraniah" from the first option while 33% of teachers chose this option. So, I suggest splitting the first option into two options: They were taught using appropriate teaching strategies and They were taught using Qa'eda Al-Nawraniah. 2. Adding the "Other" option may be a good suggestion in order not to force the teacher to choose from the available ones in case non of them was appropriate.	Yes	Same as initial version	1. Split option 1 into 2: They were taught using appropriate teaching strategies and They were taught using Qa'eda Al-Nawraniah. 2. Add"Other" option with a specify text box.
		Their dialect was pure and too close to the Standard Modern Language.					
		Self-correction between the society's members who catch this mistake (and other mistakes) then correct them.					

21	If you have other reasons, please list below.	Open ended question	All teachers agreed on its clarity.	There was a variety of answers. So it will remain an open-ended question.	No	Same as initial version	
22	Please list three other common reading difficulties you have encountered between dyslexic students	Open ended question	All teachers agreed on its clarity.		No	Same as initial version	
23	Why do you think these are the most common reading difficulties from your perspective?	Open ended question	All teachers agreed on its clarity.		No	Same as initial version	
24	Please choose the most common non-reading difficulties you have encountered between dyslexic students and effected their reading (you can choose more than one option)	Focus loss Psychological Problems. Hyperactivity. Vision Problems. Problems in differentiating between directions. Remembering. Memory problems. Emotional and behaviour problems (such as, poor self-esteem, or depression).	1. All teachers agreed on its clarity. 2. One teacher suggested using the phrase "developmental non-academic difficulties" instead of the keyword "non-reading". 3. One teacher suggested adding the "Other" option. 4. One teacher suggested adding two more options: "Math Difficulty" and "Writing Difficulty".	1. Adding the "Other" option may be a good suggestion in order not to force the teacher to choose from the available ones in case none of them was appropriate. 2. Adding the two options suggested by the teacher along with a third one "Spelling difficulties".	Yes	Same as initial version	Add 4 more options: "Math Difficulty", "Writing Difficulty", "Spelling Difficulty" and "Other" option with a specific text box.

25	Why do you think these are the most common non-reading difficulties from your perspective?	Open ended question	1. All teachers agreed on its clarity. 2. One teacher suggested to use the phrase "developmental non academic difficulties" instead of the keyword "non-reading".	1. There was a variety of answers. So it will remain an open-ended question. 2. I do not agree with the teachers' suggestions because I target any non-reading difficulties either developmental or academic.	No	Same as initial version
26	Please list three other common non-reading difficulties you have encountered between dyslexic students.	Open ended question	1. All teachers agreed on its clarity. 2. One teacher suggested to use the phrase "developmental non academic difficulties" instead of the keyword "non-reading".	1. There was a variety of answers. So it will remain an open-ended question. 2. I do not agree with the teachers' suggestions because I target any non-reading difficulties either developmental or academic.	No	Same as initial version
27	Why these are the most common non-reading difficulties from your perspective?	Open ended question	1. All teachers agreed on its clarity. 2. One teacher suggested to use the phrase "developmental non academic difficulties" instead of the keyword "non-reading".		No	Same as initial version

28	Please list three reading or non-reading difficulties you have encountered between dyslexic students that you prefer the researcher to capture.	Open ended question	1. All teachers agreed on its clarity. 2. One teacher suggested to use the phrase "developmental non academic difficulties" instead of the keyword "non-reading".	1. There was a variety of answers. So it will remain an open-ended question. 2. I do not agree with the teachers' suggestions because I target any non-reading difficulties either developmental or academic.	No	Same as initial version
29	Why do you want the researcher to capture these difficulties?	Open ended question	All teachers agreed on its clarity.	There was a variety of answers. So it will remain an open ended question.	No	Same as initial version
30	Please list three teaching strategies (ways) that improved the reading of dyslexic students:	Open ended question	All teachers agreed on its clarity.		No	Same as initial version
31	Why do you think these strategies are helpful in improving the reading of dyslexic students?	Open ended question	All teachers agreed on its clarity.		No	Same as initial version

Interactive Educational Tool Section Updates

#	Initial Version		Teacher Comments	Researcher Comments	Requires modification?	Final Version	
	Question	Answers				Question	Answers
32	How strongly do you agree on that using an interactive educational tool as an aid to train dyslexic students to read is better than using only the textbook? Why?	Strongly Agree Agree Disagree Strongly Disagree	1. All teachers agreed on its clarity. 2. One teacher suggested changing it into a sentence form instead of a question.	All teachers agreed on its clarity and only two questions used this type of question with these answers. So, I suggest leaving the question as it is in its form to standardize the way of asking questions and avoid distracting the respondents.	No	Same as initial version	
33	Reason:	Open ended question	All teachers agreed on its clarity.	There was a variety of answers. So it will remain an open-ended question.	No	Same as initial version	
34	Please choose the feature(s) that you think are useful to include in the design of an interactive educational tool for training dyslexic students on reading (you can choose more than one option):	Audio. Image. Interactivity. Verbal Feedback. Textual Feedback. Progress bar. Points. Repetition.	All teachers agreed on its clarity.	I suggest adding three more options: the "Image Feedback" option, "Animated Feedback" option and the "Other" option not to force the teacher to choose from the available options in case non of them was appropriate.	Yes	Same as initial version	1. Add Option 9: "Image Feedback". 2. Add Option 10: "Animated Feedback". 3. Add Option 11: "Other" with specify text box.

#	Initial Version		Teacher Comments	Researcher Comments	Requires modification?	Final Version	
	Question	Answers				Question	Answers
35	Please list other three feature(s) that you think are useful to include in the design of an interactive educational tool for training dyslexic students on reading.	Open ended question	All teachers agreed on its clarity.	There was a variety of answers. So it will remain an open-ended question.	No	Same as initial version	
36	Why do you want to include these features to the design of the interactive educational tool for training dyslexic students on reading?	Open ended question	All teachers agreed on its clarity.	There was a variety of answers. So it will remain an open-ended question.	No	Same as initial version	
37	Please list three feature(s) that you think should be avoided when designing an interactive educational tool for training dyslexic students on reading.	Open ended question	All teachers agreed on its clarity.	1. There was a variety of answers. So it will remain an open-ended question. 2. 63% of wrong answers. This led to a misunderstanding of the question. I suggest either rephrasing it or adding some examples.	Yes	Please list three feature(s) that you think should be avoided when designing an interactive educational tool for training dyslexic students on reading for example: avoid using distracted audio such as plyaing a sound in the background.	Same as initial version

#	Initial Version		Teacher Comments	Researcher Comments	Requires modification?	Final Version	
	Question	Answers				Question	Answers
38	Why do you want to avoid these features to the design of the interactive educational tool for training dyslexic students on reading?	Open ended question	All teachers agreed on its clarity.	1. 50% of answers were about distraction while 38% were about losing focus. 2. I suggest leaving the question as an open-ended question to capture different answers.	No	Same as initial version	
39	Please list three teaching strategies (ways) that you prefer to embed it in the interactive educational tool for training dyslexic students on reading.	Open ended question	All teachers agreed on its clarity.	1. 38% of answers were using modelling as a teaching strategy. 2. There was also a variety of answers. So it will remain an open-ended question to capture different answers if any.	No	Same as initial version	
40	Why do you prefer these teaching strategies (ways) to be embedded in the design of the interactive educational tool for training dyslexic students on reading?	Open ended question	All teachers agreed on its clarity.	There was a variety of answers. So it will remain an open-ended question.	No	Same as initial version	

Final Section Updates

#	Final Version	
	Question	Answers
41	Is there anything else would be important for me to know when teaching the student?	Open ended question

Appendix J

Exploratory Questionnaire (English Final Version)

(The Most Common Reading Difficulties between Students with Dyslexia in Saudi Schools)

Introduction:

I am a PhD student at the University of Birmingham in UK. My aim is to determine the most common reading difficulties between dyslexic students in Saudi Arabia schools from special educational teachers' perspective in order to provide them with the suitable training system that would target their needs and thus improve their reading skill. Therefore, to accomplish this aim, this survey was designed. It consists of three sections: demographic information, dyslexia and interactive educational tool. It will take 5 to 10 minutes. I hope you go through it and fill it.

Thanks for your cooperation.

Researcher: *Hadeel Mohammed Al-Dawsari*

Email: [redacted]

Section 1: Demographic Information

1. Are you a special educational teacher? (Yes, No) → if the answer is no, the questionnaire will terminate
2. What is your academic level? (Bachelor, Master, PhD, Other:..)
3. What is your gender? (Male, Female)
4. How many years of teaching experience?
5. Which city do you teach in? (e.g. Riyadh, Jeddah, Makkah, Dammam, etc.)
6. What is the educational stage you are teaching? (Primary stage, High stage)
7. Which grades do you teach? (1-12)
8. If you have taught before in another city, then please specify?

9. Please type in your email to contact you if more information is needed (optional)

Section 2: Dyslexia

10. During your teaching journey, have you ever encountered any TRUE students with dyslexia? (Yes, No) → if the answer is no, the questionnaire will terminate

    (*Note: True students with dyslexia suffer from dyslexia due to developmental issues and not due to academic neglect*)

11. Please choose the most common **reading** difficulties you have encountered between dyslexic students (you can choose more than one option):
    - Difficulty 1: Migrating the letters within the word that result to a known word. E.g. reading the word "Ya'mal" as "Ya'lam".
    - Difficulty 2: Migrating the letters within the word that result to a non-word. E.g. reading the word "Yahmel" as "Yamhel".
    - Difficulty 3: Mixing short vowels only. E.g. reading the word "kotob" as "katab".

- Difficulty 4: Mixing between long and short vowels. E.g. reading the word "Katab" as "Kaateb".
- Other, please specify: ……

12. Why do you think these are the most common **reading** difficulties from your perspective?

13. Arabic societies speak different Arabic dialects such as; Najdi dialect, Hijaz dialect, Bedwens dialect, Syrian dialect, etc. Some of these dialects pronounce some Arabic letters differently such as pronouncing Thal as Dal while others mix letters within the word such as pronounce "Melaqah" as "Maalagah".
    a) So, If you have found these reading difficulties between Arab dyslexics, then how strongly do you agree on that their dialect affected their reading? (Strongly agree, agree, disagree, strongly disagree)
    b) What is their dialect?

14. Some dyslexics are Saudis by nationality but not by their origin. So, some of them came from other Arab countries such as Syria and Egypt while others came from non-Arab countries such as Pakistan and Indonesia. Thus, they might speak their origin language as their first language in instead of Arabic. So, have you taught non-Arab dyslexics (whether their nationality is Saudi or not)? (Yes, No) → if the answer is no, the questionnaire will go to Q16.
15. If you have found these reading difficulties between non-Arab dyslexics (whether their nationality is Saudi or not), then what is their origin?

16. Have you encountered " Difficulty 1 or Difficulty 2: Migrating the letters within the word that result to a known word or a non-word"? (Yes, No)
17. If Yes, then:
    a) Why do you think it is common in your city schools? (you can choose more than one option).
        - They were not Arabs in their origin and speak Arabic as their second language.
        - They were taught using inappropriate teaching strategies.
        - They were originally Arab who mix letters positions in their dialect which affected their reading at school (e.g. Arabs from Syria region).
        - Other, please specify: ……
    b) If you have other reasons, please list below:

18. If No, then:
    a) Why do you think it is rare in your city? (you can choose more than one option).
        - They were taught using appropriate teaching strategies.
        - They were taught using Qa'eda Al-Nawraniah.
        - Their dialect was pure and too close to the Standard Modern Language.
        - Self-correction between the society's members who catch this mistake (and other mistakes) then correct them.
        - Other, please specify: ……

b) If you have other reasons, please list below:

19. Please list three other common **reading** difficulties you have encountered between dyslexic students:
    - 1.
    - 2.
    - 3.
20. Why do you think these are the most common **reading** difficulties from your perspective?

21. Please choose the most common **non-reading** difficulties you have encountered between dyslexic students and effected their reading (you can choose more than one option):
    - Math Difficulty.
    - Writing Difficulty.
    - Spelling Difficulty.
    - Focus loss.
    - Psychological Problems.
    - Hyperactivity.
    - Vision Problems.
    - Problems in differentiating between directions.
    - Remembering problems.
    - Emotional and behaviour problems (such as, poor self-esteem, or depression).
    - Other, please specify: ……
22. Why do you think these are the most common **non-reading** difficulties from your perspective?

23. Please list three other common **non-reading** difficulties you have encountered between dyslexic students:
    - 1.
    - 2.
    - 3.
24. Why these are the most common **non-reading** difficulties from your perspective?

25. Please list three **reading** or **non-reading** difficulties you have encountered between dyslexic students that you prefer the researcher to capture:
    - 1.
    - 2.
    - 3.
26. Why do you want the researcher to capture these difficulties?

27. Please list three **teaching strategies (ways)** that improved the reading of dyslexic students:
    - 1.
    - 2.
    - 3.
28. Why do you think these strategies are helpful in improving the reading of dyslexic students?

Section 3: Interactive Education Tool

29. How strongly do you agree on that using an interactive educational tool as an aid to train dyslexic students to read is better than using only the textbook? (Strongly agree, agree, disagree, strongly disagree)
30. Why?

31. Please choose the feature(s) that you think are useful to include in the design of an interactive educational tool for training dyslexic students on reading (you can choose more than one option):
    - Audio.
    - Image.
    - Interactivity.
    - Verbal Feedback.
    - Textual Feedback.
    - Image Feedback.
    - Animated Feedback.
    - Progress bar.
    - Points.
    - Repetition.
    - Other, please specify: ……

32. Please list other three feature(s) that you think are useful to include in the design of an interactive educational tool for training dyslexic students on reading:
    - 1.
    - 2.
    - 3.

33. Why do you want to include these features to the design of the interactive educational tool for training dyslexic students on reading?

34. Please list three feature(s) that you think should be avoided when designing an interactive educational tool for training dyslexic students on reading (***for example: avoid using distracted audio such as playing a sound in the background***):
    - 1.
    - 2.
    - 3.

35. Why do you want to avoid these features to the design of the interactive educational tool for training dyslexic students on reading?

36. Please list three **teaching strategies (ways)** that you prefer to embed it in the interactive educational tool for training dyslexic students on reading:
    - 1.
    - 2.
    - 3.

37. Why do you prefer these **teaching strategies (ways)** be embedded in the design of the interactive educational tool for training dyslexic students on reading?

Finally:

38. Is there anything else would be important for me to know when teaching the students? (optional)

Exploratory Questionnaire (Arabic Final Version)

(صعوبات القراءة الأكثر شيوعاً بين الطلاب المصابين بالعسر القرائي في المدارس السعودية)

المقدمة:

أنا طالبة دكتوراه بجامعة برمنجهام في المملكة المتحدة. هدفي يتمثل في تحديد صعوبات القراءة الأكثر شيوعا بين طلاب العسر القرائي في مدارس المملكة العربية السعودية من منظور معلمي ومعلمات التربية الخاصة لصياغة برنامجاً تدريبياً يستهدف احتياجاتهم لتحسين مهارة القراءة لديهم. وقد تم تصميم هذه الاستبانة لتحقيق هذا الهدف, والتي تتكون من ثلاثة أقسام: المعلومات السكانية، العسر القرائي، الأداة التعليمية التفاعلية. وتستغرق تعبئة الاستبانة من 5 إلى 10 دقائق. فضلا الاطلاع وتعبئتها.

شاكرة لكم حسن تعاونكم.

الباحثة: *هديل بنت محمد الدوسري.*

البريد الإلكتروني:

القسم الأول: المعلومات السكانية

1. هل أنت معلم تربية خاصة؟ (نعم، لا) → إذا كانت الإجابة بلا, ينتهي الاستبيان
2. مؤهلك العلمي؟ (بكالوريوس، ماجستير، دكتوراه، أخرى: ...)
3. جِنسك؟ (ذكر، أنثى)
4. كم عدد سنوات خبرتك التعليمية؟
5. في أي مدينة تُدرّس؟ (على سبيل المثال: الرياض، جدة، مكة المكرمة، الدمام.. الخ)
6. ماهي المرحلة التعليمية التي تدرّسها؟ (المرحلة الابتدائية، المرحلة المتوسطة، المرحلة الثانوية)
7. ماهي الصفوف الدراسية التي تدرّسها؟ (الأول، الثاني، الثالث، -----)
8. إذا سبق وأن درست في مدينة أخرى، فضلا حددها؟

9. فضلا أكتب بريدك الإلكتروني ليتم التواصل معك لاحقا في حال الحاجة إلى مزيد من المعلومات (اختياري).

القسم الثاني: العسر القرائي

10. خلال رحلتك التعليمية، هل سبق وأن واجهت طلاب يعانون من العسر القرائي الحقيقي (نعم، لا)→ إذا كانت الإجابة بلا, ينتهي الاستبيان

(ملاحظة/ يعاني الطلاب المصابون بالعسر القرائي الحقيقي من عسر القراءة بسبب مشاكل نمائية وليس بسبب الإهمال الدراسي).

11. فضلا اختر صعوبات القراءة الأكثر شيوعًا التي واجهتها بين الطلاب الذين يعانون من العسر القرائي (يمكنك اختيار أكثر من خيار واحد):
    - الصعوبة الأولى: التبديل بين أماكن الأحرف داخل الكلمة (شقلبة الكلمة) والحصول على كلمة أخرى صحيحة مشابهة لها في الشكل ومختلفة عنها في المعنى. على سبيل المثال قراءة كلمة "يعمل" كـ "يعلم".
    - الصعوبة الثانية: التبديل بين أماكن الأحرف داخل الكلمة (شقلبة الكلمة) والحصول على كلمة أخرى غير صحيحة مشابهة لها في الشكل فقط. على سبيل المثال قراءة كلمة "يحمل" كـ "يمحل".
    - الصعوبة الثالثة: الخلط بين الحركات القصيرة. على سبيل المثال قراءة كلمة "كُتُب" كـ "كَتَب".
    - الصعوبة الرابعة: الخلط بين الصوت القصير والطويل. على سبيل المثال قراءة كلمة "كَتَب" كـ "كَاتِب".
    - أخرى، فضلا حدد:.....
12. لماذا تعتقد أن هذه هي صعوبات القراءة الأكثر شيوعًا من وجهة نظرك؟

13. "تتحدث المجتمعات العربية لهجات مختلفة مثل: اللهجة النجدية، اللهجة الحجاز، اللهجة البدوية، اللهجة السورية، إلخ. بعض تلك اللهجات تنطق بعض الحروف العربية بطريقة مختلفة كنطق الذال وكأنه دال. بينما يشقلب البعض الآخر الحروف داخل الكلمة كنطق "ملعقة" كـ "معلقة".

أ. إذا وجدت صعوبات القراءة هذه بين الطلاب العرب الذين يعانون من العسر القرائي، فما مدى اتفاقك مع أن لهجتهم الأم أثرت على قراءتهم؟ (أتفق بقوة, أتفق, لا أتفق, لا أتفق بقوة)

ب. ماهي لهجتهم؟

14. بعض الطلاب السعوديين الذين يعانون من العسر القرائي سعوديوا الجنسية وليس أصلهم. فبعضهم يعود أصله إلى دول عربية أخرى مثل سوريا ومصر, بينما البعض الآخر يعود إلى دول غير عربية مثل الباكستان وإندونيسيا وماليزيا. وبالتالي، قد يتحدثون لغتهم الأصلية كلغة أولى بدلاً من اللغة العربية. فهل درست طلابا غير عرب يعانون من العسر القرائي (سواء كانوا سعوديي الجنسية أم لا)؟ (نعم/ لا)→ إذا كانت الإجابة بلا فينتقل مباشرة الى السؤال 16

15. إذا وجدت صعوبات القراءة هذه بين الطلاب غير العرب الذين يعانون من العسر القرائي، (سواء كانوا سعوديي الجنسية أم لا) فما هو أصلهم؟

16. هل واجهت "الصعوبة الأولى: التبديل بين أماكن الأحرف داخل الكلمة (شقلبة الكلمة) والحصول على كلمة أخرى صحيحة مشابهة لها في الشكل ومختلفة عنها في المعنى" أو "الصعوبة الثانية: التبديل بين أماكن الأحرف داخل الكلمة (شقلبة الكلمة) والحصول على كلمة أخرى غير صحيحة مشابهة لها في الشكل فقط." (نعم، لا)؟

17. إذا كانت الإجابة بنعم:

أ. فلماذا تعتقد أنها شائعة في مدينتك؟ (يمكنك اختيار أكثر من خيار).

- ○ ليست أصولهم عربية ويتحدثون العربية لغة ثانية.
- ○ تم تعليمهم باستخدام استراتيجيات التدريس غير المناسبة.
- ○ كانوا في الأصل عرباً يخلطون أماكن أحرف الكلمة في لهجتهم الأم مما أثر على قراءتهم في المدرسة (على سبيل المثال عرب بلاد الشام).
- ○ أخرى، فضلا حدد:.....

ب. إذا كانت لديك أسباباً أخرى، فضلا أذكرها:

18. إذا كانت الإجابة بلا:

أ. فلماذا تعتقد أنها نادرة في مدينتك؟ (يمكنك اختيار أكثر من خيار).

- ○ تم تعليمهم باستخدام استراتيجيات التدريس المناسبة.
- ○ تم تعليمهم باستخدام القاعدة النورانية.
- ○ كانت لهجتهم نقية وقريبة جدًا من اللغة الفُصحى.
- ○ التصحيح الذاتي بين أفراد المجتمع الذين التقطوا هذا الخطأ (وأخطاء أخرى) ثم صححوها.
- ○ أخرى، فضلا حدد:.....

ب. إذا كانت لديك أسباباً أخرى، فضلا أذكرها:

19. فضلا أذكر ثلاث صعوبات قراءة شائعة أخرى واجهتها بين الطلاب المصابين بالعسر القرائي.

- ○ 1.
- ○ 2.
- ○ 3.

20. لماذا تعتقد أن صعوبات القراءة هذه هي الأكثر شيوعًا من وجهة نظرك؟

21. فضلا اختر صعوبات غير القراءة الأكثر شيوعًا والتي واجهتها بين الطلاب الذين يعانون من العسر القرائي وأثرت على قراءتهم (يمكنك اختيار أكثر من خيار واحد).
    - صعوبة في الكتابة.
    - صعوبة في الإملاء.
    - صعوبة في الرياضيات
    - فقدان التركيز.
    - مشاكل نفسية.
    - فرط في الحركة.
    - مشاكل في الرؤية.
    - مشاكل في التمييز بين الاتجاهات.
    - مشاكل في التذكر.
    - مشاكل عاطفية وسلوكية (على سبيل المثال: ضعف الثقة في النفس، الاكتئاب)
    - أخرى، فضلا حدد:.....

22. لماذا تعتقد أن صعوبات غير القراءة هذه هي الأكثر شيوعًا من وجهة نظرك؟

23. فضلا أذكر ثلاث صعوبات غير القراءة شائعة أخرى واجهتها بين الطلاب المصابين بالعسر القرائي.
    1.
    2.
    3.

24. لماذا تعتقد أن صعوبات غير القراءة هذه هي الأكثر شيوعًا من وجهة نظرك؟

25. فضلاً أذكر ثلاث صعوبات قراءة أو غير القراءة والتي واجهتها بين الطلاب الذين يعانون من العسر القرائي وتفضل أن يستهدفها الباحث.
    1.
    2.
    3.

26. لماذا تريد الباحث أن يستهدف هذه الصعوبات؟

27. فضلاً أذكر ثلاث طرق (استراتيجيات) تدريس أدت إلى تحسين قراءة الطلاب الذين يعانون من العسر القرائي.
    1.
    2.
    3.

28. لماذا تعتقد أن هذه الطرق مفيدة في تحسين قراءة الطلاب الذين يعانون من العسر القرائي؟

القسم الثالث: الأداة التعليمية التفاعلية

29. ما مدى اتفاقك مع أن استخدام أداة تعليمية تفاعلية كوسيلة مساعدة لتدريب الطلاب الذي يعانون من العسر القرائي على القراءة أفضل من استخدام المقرر الدراسي فقط؟ (أتفق بقوة, أتفق, لا أتفق, لا أتفق بقوة).
30. لماذا؟

31. فضلاً اختر الميزة (الميزات) التي تعتقد أن إضافتها في تصميم الأداة التعليمية التفاعلية مفيد لتدريب الطلاب الذين يعانون من العسر القرائي على القراءة (يمكنك اختيار أكثر من ميزة):
    - الصوت.
    - الصورة

- التفاعل.
- التغذية اللفظية الراجعة.
- التغذية الحركية الراجعة.
- التغذية الصورية الراجعة.
- التغذية النصية الراجعة.
- شريط التقدم.
- النقاط.
- التكرار.
- أخرى، فضلا حدد:.....

32. فضلاً أذكر ثلاث ميزات أخرى تعتقد أن إضافتها في تصميم الأداة التعليمية التفاعلية مفيد لتدريب الطلاب الذي يعانون من العسر القرائي على القراءة.

- 1.
- 2.
- 3.

33. لماذا تريد إضافة تلك الميزات في تصميم الأداة التعليمية التفاعلية لتدريب الطلاب الذين يعانون من العسر القرائي على القراءة؟

34. فضلاً أذكر ثلاث ميزات تعتقد أنه يجب تجنبها عند تصميم الأداة التعليمية التفاعلية لتدريب الطلاب الذي يعانون من العسر القرائي على القراءة. (على سبيل المثال: تجنب استخدام الأصوات المشتتة مثل تشغيل صوت في الخلفية)

- 1.
- 2.
- 3.

35. لماذا تريد تجنب تلك الميزات في تصميم الأداة التعليمية التفاعلية لتدريب الطلاب الذين يعانون من العسر القرائي على القراءة؟

36. فضلاً أذكر ثلاث طرق (استراتيجيات) للتدريس تفضِّل إضافتها في تصميم الأداة التعليمية التفاعلية لتدريب الطلاب الذي يعانون من العسر القرائي على القراءة.

- 1.
- 2.
- 3.

37. لماذا تفضِّل إضافة طرق التدريس هذه في تصميم الأداة التعليمية التفاعلية لتدريب الطلاب الذين يعانون من العسر القرائي على القراءة؟

وأخيرا..

38. هل هناك شيئا آخر مهمًا يجب أن أعرفه عند تدريس الطلاب؟ (اختياري)