Understanding the Sequence of Learning in Arabic Text -- Saudi Arabian Dyslexics and Learning Aid Software

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ABSTRACT: Dyslexic individuals have serious difficulties in learning to read, and several software programs have been developed to overcome them. Previous research studies found that in most cases, providing correct spelling and word recognition with greater accuracy constitutes the key function. However, more research has to be conducted on the software programs for dyslexia. Another issue is visual-spatial attention; the aspect of directing attention to a location of what should be learnt while reading has been ignored in most studies. This research analysis of the previous studies outlines some research gaps as follows: recording children's eye movements during reading were uncertain. Another research gap is understanding the frequencies of Arabic word recognition for dyslexic children the meaning of the Arabic word during reading for dyslexic were not adequately presented in the previous research. Therefore, this paper presents an experimental study on identifying Arabic words and their meaning by dyslexic individuals focusing on the sequence of interactions. A decision-making analysis of the key interactive components of the Arabic alphabet puzzle app for dyslexics is performed, and the finding of the study reveals that the speed and accuracy of visual word recognition and meaning description increases and significantly influences visual short-term memory The analysis of the most important factors that influence all the other factors of the user experience of the Arabic alphabet puzzle app for dyslexics shows that 'desirability' constitutes the key attribute in enhancing visual-spatial attention and accelerating word recognition and meaning description for Arabic-speaking dyslexics.

Keywords: Eye Tracking, Reading, Dyslexia, Visual word, Visual stimuli

1. Introduction

Dyslexia constitutes a specific learning disability. It is defined as an impairment in the acquisition of reading and spelling abilities that manifests in neurodevelopmental reading difficulties (Reid, Shaywitz, & Shaywitz, 2013). One of the most common symptoms of the disorder is related to the difficulties experienced in word recognition. Dyslexia is caused by various genetic and environmental risk factors as well as their interaction (Peterson, and Pennington, 2015), although some studies have revealed that a final understanding of the causes of dyslexia or agreement on its precise definition has yet to be reached (Benfatto, Seimyr, Ygge, Pansell, Rydberg, & Jacobson, 2016). Its prevalence is attested by the fact that certain individuals experience persistent problems in learning to read for no apparent reason. Since reading constitutes a primary area of learning, this is consistently problematic. It may be the case that one individual struggles with reading and spelling while another has difficulty in understanding verbal communication. Dyslexia issues manifest in various aspects of learning. The major research question of this study focuses on whether software programs offer a solution for dyslexia. A number of practical approaches have been developed to assist dyslexic individuals based on certain software programs. Among the common software applications available in the public domain are "4 Pics 1 Word – Free," "A+ Spelling Test," "A1 Spelling App," "ABC Magic Phonics," "Leo-Recorder and Transcriptions," and "Reading Machine Free." However, in terms of aiding learning difficulties in reading, several issues have remained unclear and certain specific learning processes have been ignored such as the fact that it constitutes an assembling the sequence of events. In respect to the complexity of co-ordination in learning, sequencing and organizational difficulties with individual with dyslexia may benefit from certain technologies that allow them to concentrate on the content rather than the process (Smythe, 2010).

Even though dyslexics behave normally and are obviously intelligent, their condition always manifests in their difficulty to acquire reading abilities. This is what is clearly known about dyslexia for which several remedies have been proposed. Among the most feasible remedies is the use of educational counselling and tutoring. Unfortunately, this approach involves certain drawbacks, especially in terms of language rules and writing system. Considering that dyslexia is more prominent in children (Adlof & Hogan, 2018), adults also are affected. Its signs can be recognized as taking a long time before talking, difficulty in learning new words faster, extreme difficulty in framing words correctly, confusing words that sound alike, and difficulty in remembering or naming letters, numbers and colours. These attributes can be corrected by software programs that may come in the form of games or any interactive software programs.

The majority of available software applications for aiding dyslexics in general mostly relies on the so-called "recency effect" meaning an order of learning effect that relies on reflection of recent presentation (Cockburn et al., 2015). However, the "serial position effect" may aid dyslexic individuals more as it allows them to remember what has been learnt first and the last thing that was learned in a series (Corina, 2015). This falls under the category of "visual-spatial attention." In this study it is described as a form of directing attention to a location of what should be learnt during reading. Visual-spatial attention has been identified as a crucial predictor of reading abilities (Gabrieli & Norton, 2012). It has been suggested as an early way of identifying dyslexia, especially in pre-schoolers and predicts future reading acquisition. Considering this in the context of Arabic language acquisition, the Arabic alphabetic puzzle game application using eye tracking and chatbot proposed in Aljojo et al. (2018) is used in this study in order to examine how eye tracking can be used to improve the reading ability of dyslexic individuals when learning how to read. Visual-centric issues in software programs for educating and tutoring dyslexia remain a major concern. Individual learning behaviour is based on the intention, which in turn is influenced by the learning attitude. Visual properties are crucial to learning any software program. Some studies revealed that reading and object recognition (colour vision and high acuity) takes about 1.5° area responsible for sharp central vision (the fovea) (Bodis-Wollner, 2013). Visual effect is very important as a minimum of 3–4 and a maximum of 10 to 12 letters during reading appears visible in detail at any time during reading for a normal individual (Rayner et al., 2011). Research gaps were established based on the fact that previous studies ignored subjective evaluation of dyslexics and focus more software base intervention. Furthermore, the previous studies also disregarded recording children's eye movements during reading by observations. Another research gap is understanding the frequencies of Arabic word recognition with a Software program. The question whether the high visual outlook of a software program is the solution to dyslexics can be studied and answered by creating an experimental setting. Although experiments are known to alter the participant's responses and even create bias, they are useful in extracting facts and produce a sufficiently high amount of data. The current study relies on the user's perception in order to obtain statistically valid quantitative results through Arabic word recognition, finding and fixing missing puzzle as well as identifying the meaning of the word. The outcome of the study can be generalized with strong justifications. Hence, the proposed research questions are: How is dyslexics children's eye movements influence their reading comprehension? How is dyslexics children's frequencies of Arabic word recognition influence their reading comprehension.

The remaining part of the paper is organized as follows: Section 2 presents the related work; Section 3 describes and explains the research methodology; Section 4 offers the experimental analysis; Section 5 summarizes the results; and Section 6 completes the study with the conclusion and recommendation.

2. Related work

The application that has been developed was based on Arabic vowels and the graphical objects with eye tracker and chatbot to monitor and motivate dyslexic individuals. This complete technology package offers an efficient platform to increase the learning abilities of dyslexics (Aljojo et al., 2018). It is aimed at children aged four to seven who have dyslexia, including symptoms such as excessive movement and dispersed attention. Individuals who are unable to read normally due to their disability can also use this type of application to facilitate their learning process. This application is a puzzle-based game that utilizes eye tracking and chatbot to ensure that the user does not lose focus and keeps attention. The implementation process relies on the users' perception of how the game will work and how the application will provide helpful information that will support and simplify their needs.

Previous related studies have discussed various techniques for developing software/hardware suitable for individuals with dyslexia. Video games have been used for dyslexia correction. It was revealed that software video games have gained considerable popularity as they provide an enlarged size field of view and an adequate sequence of visual display (Green & Bavelier, 2003). Interestingly, it was also found out that the beneficial effects of certain kinds of software video game displays helped increase reading abilities (Franceschini et al., 2015). Another study has indicated that children with dyslexia who used a software video game showed an improvement in visuo-spatial and temporal attentional shifting matched with an improvement in reading speed without any increase in reading errors rate (Franceschini et al., 2015).

Individuals with dyslexia are given the opportunity to detect errors while reading which might improve their skills attributable to the very high degree of spelling-sound consistency (Bavelier et al., 2013). Many dyslexia educational and tutoring aided software programs available in the public domain are intended to achieve precisely that. The A1 Spelling App focuses on sound by engaging the learner to listen to vocabulary being spoken and repeat after the software program. ABC Magic Phonics uses a combination of a photo for each phonetic presented alongside with suggestions. Leo-Recorder and Transcriptions software program record and transcribe. Reading Machine Free is software program that shows how a word sounds and also how letters are combined from taken from the user's voice. The A+ Spelling Test software program allows the user to listen to a word he or she then spells and corrects it if needed. Shah (2012) also proposed a learning app suitable for dyslexia (1000 Sight Words Superhero). It is a software program developed for comparative word sets that involve 1,000 common words and their known counterparts. These words are organized in such a way that they can be matched to each other and their synonyms. Learners start with a set of 10 words and match them with other words that have the same meaning. Even though the program allows for an organized way of learning vocabulary, the level of provided interaction and action towards learning correct spelling and word recognition with greater accuracy has not been taken into account in this app. Lotum (2017) has recently developed a software program that uses images within puzzles to aid individual learners to identify correct words. The users point out right words following a set of rules as they progress. Unfortunately, visual-spatial attention and acceleration of recognition has not been taken into account in this app.

While the majority of the previous studies focused on developing full-fledged dyslexia tutoring apps, the analysis of visual content accuracy has not always been considered. It has been found that in textual search interfaces the dyslexic user's performance increases when icons are included in the search user interfaces (Berget et al., 2016). Text presentation within dyslexia tutoring app has been identified as a crucial element. Specifically, font types without serifs are considered as the most preferable for dyslexics (Evett & Brown, 2005) that also affect their reading performance (Rello & Ballesteros, 2015). Another study has revealed that dyslexics generally prefer designs with large text and images (Williams & Hennig, 2015), yet it is still unclear whether these conditions influence performance. This is also supported with the findings of Al-Wabiletal (2007), which indicated that dyslexics faced some enormous navigational drawbacks online, even on a platform with large text and images. In the context of visual spatial attention, Gabrieli and Norton (2012) studied the importance of visual spatial attention and observed that it constituted one of the major factors that influence reading abilities. Typically, the left side of visual space affect s the visual-spatial attention and it is the cause of abnormal function in reading behaviors (Nagamatsu et al., 2009). Franceschini et al. (2012) revealed that visual-spatial attention predicts the reading capabilities and the future performance in reading acquisition in preschoolers. Other studies reveal various conditions of the effect of Eye movements (Clifton et al., 2016), eye movement on word length and frequency on fixation (Kuperman & Van Dyke, 2011), eye movement orientation (Chang et al., 2016), and eye-tracking (Paracha et al., 2018) and (Frutos-Pascual & Garcia-Zapirain, 2015) with respect to reading ability.

It is furthermore worth mentioning that the aforesaid works (Aljojo et al., 2018; Shah, 2012; Green & Bavelier, 2003; Franceschini et al., 2012; Franceschini et al., 2015; Bavelier et al., 2013) focused on interactive practices of learning reading. However, how to employ eye movement or eye tracking on learning reading for practical applications has not been greatly discussed. Hence, following the previous successful applications of eye movement and word skipping during reading (Rayner et al., 2011), and the success of visual-spatial attention in reading (Franceschini et al., 2012 & Gabrieli & Norton, 2012), this paper presents the findings on how visual-spatial attention influences visual accuracy for dyslexics.

3. Methodology

The research methodology adopted for this study involves visual-spatial attention and multi-decision criteria analysis. The visual attention experiment was concerned with finding the missing puzzle, any change-detection from the way the participant gazed, were observed. The behavior of the participant's eye-movement on change-detection accuracy of finding the right puzzled was measured. The experiment established how the spatial locations occupied visual space of missing puzzle when they were no longer visible. The visual-spatial attention experiment was preceded by the multi-decision criteria analysis (Jasri & Rahim. 2017; Carpitella et al., 2018), decision-making trial and evaluation laboratory (DEMATEL) (Chang et al., 2011; Lee et al., 2013; Zhou et al., 2017). This was carried out in order to examine the key interaction component of visual-spatial attention of an eye tracking Arabic alphabetic puzzle app for dyslexia. While the visual-spatial attention experiment was set out to reveal the visual accuracy for dyslexics reading skills, the DEMATEL focused on investigating the key attributes of visual-spatial attention of the app. These methods were chosen based on the discrepancies of research on dyslexia tutoring software programs' nature of adoptions.

3.1. Visual-spatial attention experiment

This paper constitutes an extension of the work of Aljojo et al. (2018) who proposed an eye tracking and chatbot Arabic alphabetic puzzle game application for dyslexia. The application consists of three levels, namely a group of similar Arabic letters, vowels, and a play exercise. The play exercise page contains a gaming and learning activity. If the participant answers correctly, he/ she can access a game that is related to the same letter. The idea for developing the application was due to the lack of the sequence of interaction provided for Arabic word recognition, finding and fixing a scrambled puzzle, and identifying the meaning the words generated. Hence, a review was conducted for some available applications in the public domain.

3.1.1. Participants

A sample of 42 Saudi Arabian dyslexic children was used for the control experiment of this study. The 42 children used for the control experiment of this study are all in control group and, their parents are involved in the experimental, as a result only one group experiment was analyzed in order to avoid epistemological bias since parents are involved. 14 of them were males and the remaining 28 were females. The participant mean age was 9.12 years (range 8.1–13.9). All the children were recruited through their parents from different regions of Saudi Arabia. They are all Arabic natives and their literacy level in Arabic is at Primary school level the participants' parents completed a full review of the experimental details and were given the software program from Aljojo et al. (2018). Following the parents' consent to have their children participate in this study, two important criteria were set out as follows: The children had not been exposed to the software program from Aljojo et al. (2018) and were not aware of it; until the parents acquired the knowledge of the apps and then performed the prior experiment to lead them have knowledge about the content provided by the app before using the it. All participants were confirmed as diagnosed with dyslexia with no history of neurological disease.

3.1.2. App

The Arabic Alphabetic Puzzle Game Using Eye Tracking and Chatbot for Learning Disability (Dyslexia) (Aljojo et al., 2018) was used for the experiment (see Figure 1). Figure 2 presents the text base content that directly displays the Arabic letters with puzzles, three Arabic letter words supposedly constituting the minimum number of letters any normal individual can capture while reading (Rayner et al., 2011).

3.1.3. Research instrument and data collections

The pre-field experimental study was carried out with the participants two to four days before running the main experiment and follow-up experiment between the first and the last day, similar to some previous studies (Franceschini et al., 2013; Gori et al., 2013). The software program of Aljojo et al. (2018) developed for a mobile device was run for the participant. The matching puzzles were set and the missing words are completed. Each child was individually treated for three sessions for three days over a period of three weeks.

In terms of tasks administration and evaluation, all reading performances of the participants were recorded and time and errors were coded by Native-Arabic speakers. This works by observations, during the reading experiment (See Figure 1). It is an ethnographical observational exercises, specifically, covert observational approach in which the participants are not aware of the recording of their reading performance. The performance is defined as accurately reading correctly while the frequency of eye movement recorded. The errors are defined as the inaccuracies of reading, involving mismatch, mispronunciation of words, skipping of words. The researchers are Native-Arabic, they are aware of the accurately recording of the participants' reading performance, based on Rayner et al. (2013) who revealed that the potential utility of recording children's eye movements during reading when conducting future applied research is not by technology, it is by care repeated overt observation.

Figure 1. Group of Arabic letters to be identified and read by the participants

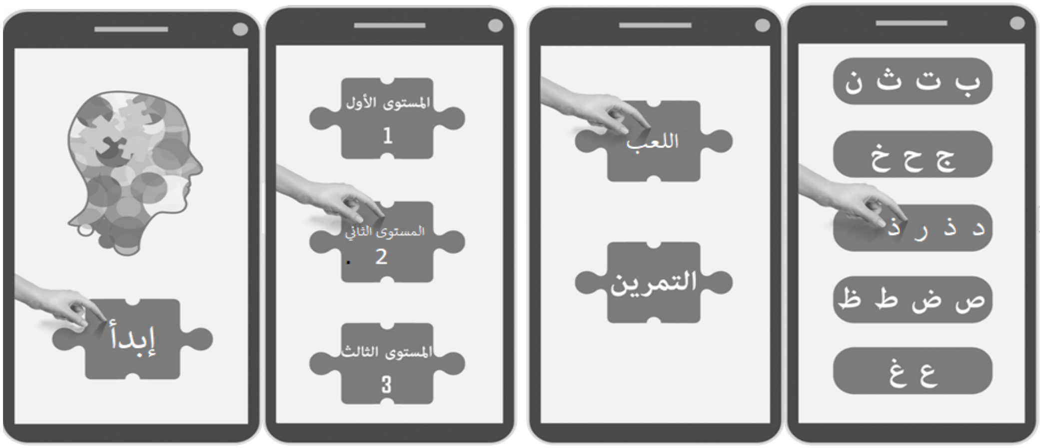

Figure 2. Group of Arabic letters to be identified and read by the participants

After choosing the group of similar notes, the dyslexics used one letter and compared it with more than one vowel, starting from left to right as shown in Figure 3. After choosing the vowel, the app was now ready to start playing and learning. The puzzle image and letters were used for the exercise. It started by asking the children to complete the puzzle. Later, any missing word from the puzzle ended in the final exercise where they had to choose the correct letter to make the word correct.

The puzzling sequence viewing distances were set not far apart. The participants were instructed to make sure that their eyes were kept in focus and followed the puzzle position from the starting point of the trial to the end. Each trial started with the first sequence of the puzzling and ran through the last. Hence, the eye tracking in the focused condition was noticed on the target location of the puzzle piece. Where the participants got the missing puzzle piece right or wrong, their eye movement was recorded, in addition to the time taken for that movement. The participants were also instructed to identify and compare their target within the puzzle.

Figure 3. The puzzled sequence of Arabic letters

3.2. DEMATEL evaluation criteria

DEMATEL is regarded as one of the key methods for evaluating interactive user experiences by linking the various functions in identifying the interdependence among by evaluation (Si et al., 2018). This technique has gained popularity due to its ability to indicate whether each criterion belongs to the cause or the effect group. The technique allows participants to make judgments by assigning weightages to show how one criterion influences another criterion. This allows to establish the interdependent relationships among the factors. As a result, they can be ranked for long term strategic decision. There are two major procedures for undertaking DEMATEL evaluation analysis, namely data gathering/collection step and interrelationships analysis step.

The data collection requires gathering expert opinion. In this study, the parents of the participants that participated in responding to a structural questionnaire that was designed based on the user's experience attributes developed by Morville (2004). The DEMATEL requirement for "expert" is referring to "the awareness of the subject." The justification of adopting Morveille's user experience design factors lie with the fact that apps meant for aiding individual learning processes, especially dyslexics, should contain certain features such as speaking aid, reading aid, spelling aid, and writing aid. Although visual aids were mostly ignored for the reason that dyslexia do not involve visual disability, Stein (2014) argued that "many dyslexics have problems with clearly seeing letters and their order" This is an abnormal condition of visual magnocellular nerve cells that mediate the capability to swiftly recognize letters and their order. It is the central control of visual guidance of individual attention of eye fixations. Based on this observation, the user experience attributes for software programs intended for helping dyslexics in ways that are in line with the evidence on how to help dyslexics are evaluated. According to Morveille (2004), seven important factors are believed to be the user experience criteria, namely: "Useful," "Usable," "Findable," "Credible," "Desirable," "Accessible," and "Valuable." "Useful" refers to the benefits obtained from an eye tracking Arabic alphabetic puzzle app for dyslexia. "Usable" means how an eye tracking Arabic alphabetic puzzle app for dyslexia effectively and efficiently achieves the learning aid for dyslexics. "Findable" refers to how easier it is to find the missing puzzle piece in an eye tracking Arabic alphabetic puzzle app for dyslexia. "Credible" is the ability of the user to trust the learning path established through an eye tracking Arabic alphabetic puzzle app for dyslexia. "Desirable" refers to the extent which dyslexics desire to use an eye tracking Arabic alphabetic puzzle app for dyslexia. "Accessible" refer to how the content of an eye tracking Arabic alphabetic puzzle app for dyslexia reachable to dyslexics. "Valuable" refers to the value an eye tracking Arabic alphabetic puzzle app for dyslexia towards learning. The questionnaire was used to collect data in order to assess the relationships between the established factors. These were decided by the expert and used to establish a group direct-influence matrix. The direct relation matrix indicated a direct influence each factor on the other and evaluated through an integer scale of "no influence (0)," "low influence," "medium influence," "high influence," and "very high influence" as precondition of using this analysis. Therefore, the influence of each criterion is x_{ij}, where $_i$ and $_j$ were assigned as the cause and effect criteria respectively. As a result, the total number of the participants' responses could be represented by $n = 1, 2\ldots, n$, and $n \times n$ was a non-negative direct relation matrix generated by equation 1.

$$x^y = [x_{ij}^y]_{n \times n} \qquad (1)$$

where y was the total number of responses by each expert for which $1 \le y \le q$ and matrix q for $x^1, x^2, \ldots, x^q$ where q was also the number of responses. The average expert's decision matrix, $Z = [z_{ij}]$ was generated by equation 2:

$$z_{ij} = \frac{1}{l}\sum_{k=1}^{l} z_{ij}^{k}, \quad i, j = 1, 2, \ldots, n. \qquad (2)$$

Immediately after generating the direct influence matrix, the next step of normalizing the direct influence matrix to X was taken where X = Z/s, and ***s*** was defined as:

$$s = \max\left(\max_{1 \le i \le n} \sum_{j=1}^{n} z_{ij}, \max_{1 \le i \le n} \sum_{i=1}^{n} z_{ij}\right) \qquad (3)$$

After normalizing the direct influence matrix, the total influence matrix (T) was generated by

$$T = X + X^2 + X^3 + \cdots + X^h = X(I - X)^{-1}, \quad \text{when } h \longrightarrow \infty,$$

where ***I*** was denoted as an identity matrix that generated the Cause and Effect Relationship. The parameters that determined the causal and effect were D and R respectively, where the following equations were used:

$$D_i = \sum\nolimits_{i=1}^{n} t_{ij}, i = 1, 2, \ldots, n \qquad R_i = \sum\nolimits_{j=1}^{m} t_{ij}, j = 1, 2, \ldots, m$$

Here, R_i represented the direct and indirect influence of the criteria ''*i*'' over the other criteria, and D_j represented the influence received by "*j*" by the other criteria. The causal relationship graph was developed by the net effect value and thus ***D-R*** and ***D+R*** were computed. ***D*** and ***R*** represented the sum of the rows and the sum of the columns, respectively, from the total-influence matrix. ***D+R*** indicated how much importance the criterion had and showed the degree of relation between a criterion and all the other criteria. High value of ***D+R*** meant that the criterion had a high relation with other criteria while low ***D+R*** meant that the criterion had a low relation with other criteria. ***D-R***, on the other hand, indicated the kind of relation among criteria. While a positive ***D-R*** indicated that the criterion belonged to the cause group (dispatcher), a negative ***D-R*** indicated that the criterion belonged to the effects group (receiver).

4. Analysis and presentation results

After pre-field experimental study which familiarized the participant on the use of the Aljojo et al. (2018) software program, the recognition, reading and matching of the missing puzzled were set out. Each participant's interaction with three Arabic letter words in the software program for the "Arabic Word Recognition" at phonological level, "Finding missing puzzle" at morphological level, "Fixing missing puzzle" at morphological level, and "Arabic Word Meaning" at lexical level over some period of time was recorded (see Figure 1). The number of errors made during the experiment was collected.

The longest time it took for the Arabic word recognition from the start of the experiment to the end for all participants was found to be seven (7) seconds, as measured in the case of two participants (see Figure 3). Only one participant was able to recognize the three words within two seconds, which is the fastest time it took for the recognition.

The period of finding and fixing the Arabic word puzzle by the participant was recorded (see Figure 4). The fastest time was 43 seconds, whereas the longest time it took to find and fix the missing puzzles was 77 seconds. Finding the puzzle piece was believed to occur after recognition at the beginning of the experiment. The task of finding the puzzle piece involved first understanding the unscrambled Arabic letters and words. The participants picked and entered the missing letters into the puzzle. Therefore, it took some time for the participants to make their decisions, which was the part in which the dyslexics' abilities were measured. As a result, the participants' eye movements within the visual-spatial attention were examined to be directed by the decision after recognition and before finding the missing puzzle piece (see Figure 5).

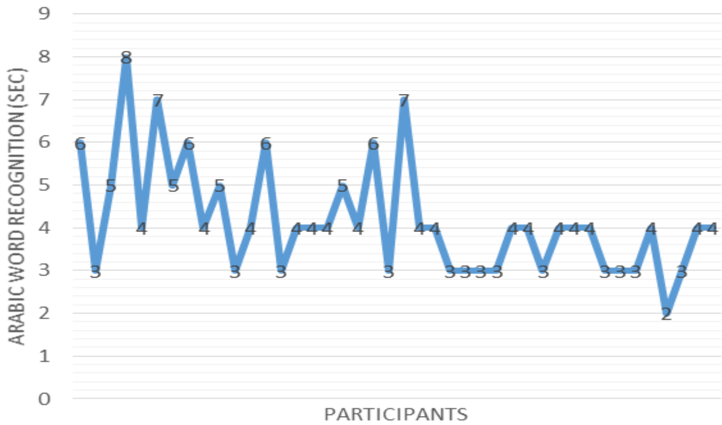

Figure 4. Frequencies of Arabic word recognition for dyslexic children

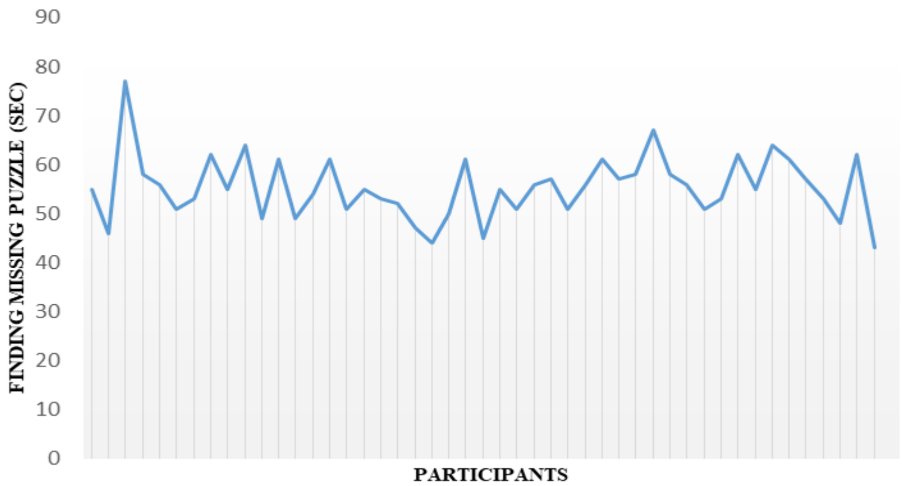

Figure 5. Time taken to find and fix Arabic word puzzle pieces

After Arabic word identification, finding and fixing the missing puzzle piece, the final part was to identify the meaning of the words. The sequence of the events was completed when the participant read the words after finding the missing puzzle and describing its meaning. One of the major results for this last task was to determine whether the participants correctly described the meaning of the word. The time taken for the participant to describe the meaning of the Arabic word was recorded (see Figure 6). The fastest time was two seconds, which was accomplished by most of them while the longest time it took for a participant to describe the meaning was four seconds.

Further analysis of the experimental results revealed that the level of word recognition and understanding of the meaning improved from the analysis of Covariance (ANCOVA). Word recognition and understanding of the meaning are two variables that are measure in order to see the degree of how they joint together, similar to how Green and Bavelier (2003) used covariance measure. Not including the preliminary analysis of Finding and Fixing the Missing Piece, Word Recognition as the dependent variable while the possible effects of Describing the Meaning of Words and Time for Recognition were controlled by entering them as covariates. The Time for Recognition was significant ($F(1,42) = 4.72$, $p = .002$, $\eta^2 = .12$) while the treatment of post-hoc comparisons indicated that the participant's Word Identification significantly decreased their Word Meaning Description. There was an improvement in Finding and Fixing the Missing Piece and the Description of Word Meaning. The time used for the tasks (in seconds) showed an improvement of Description of Word Meaning and the majority of the participants had improved in Word Meaning Description accuracy. The accuracy of the completed Description of Word Meaning over time and Eye Movement tasks was analysed in order to evaluate the visual-spatial attention (decision processing) and regression analysis was carried out. The dependent variable was Arabic Word Meaning Description and the predictors were Finding and Fixing the Missing Piece and Arabic Word Identification. Finding and Fixing the Missing Piece accounted for 71% of the unique variance of being able to describe the meaning of the words ($p = .001$), thus demonstrating that the use of an eye tracking and chatbot Arabic alphabetic puzzle game application for dyslexia did indeed result in reading remediation.

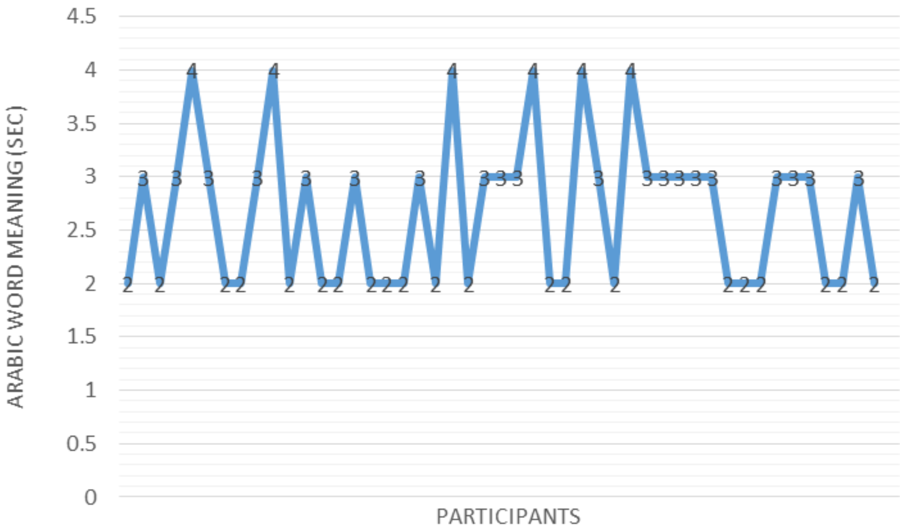

Figure 6. Time taken for revealing the meaning of the Arabic word

The analysis of the key criteria that influenced the app used for dyslexics was carried out using the DEMATEL approach. After the data collection, the first step in obtaining the analysis result involved coding the criteria and entering the data in MS Excel. The criteria were coded as follows: "Useful (UF)," "Usable (UA)," "Findable (FD)," "Credible (CR)," "Desirable (DE)," "Accessible (AC)," and "Valuable (VL)." After calculating the direct influence matrix with equation 1, the result was presented in Table 1. Thereafter, the direct influence matrix was normalized by equation 2 and the result was presented in Table 2.

Table 1. Direct influence matrix

Criteria	UF	UA	FD	CR	DE	AC	VL
UF	0.000	3.207	2.929	2.897	3.069	3.207	2.931
UA	3.267	0.000	3.267	3.172	3.207	3.167	3.067
FD	2.821	2.714	0.000	2.923	2.929	2.929	2.786
CR	2.821	3.000	2.893	0.000	3.154	2.821	2.821
DE	2.857	3.148	3.250	3.321	0.000	3.357	3.107
AC	3.107	2.929	3.036	3.107	2.964	0.000	2.821
VL	3.036	2.929	2.750	2.750	2.821	2.964	0.000

Table 2. Normalized direct influence matrix

Criteria	UF	UA	FD	CR	DE	AC	VL
UF	0.000	0.168	0.153	0.151	0.160	0.168	0.153
UA	0.171	0.000	0.171	0.166	0.168	0.165	0.160
FD	0.147	0.142	0.000	0.153	0.153	0.153	0.146
CR	0.147	0.157	0.151	0.000	0.165	0.147	0.147
DE	0.149	0.164	0.170	0.173	0.000	0.175	0.162
AC	0.162	0.153	0.159	0.162	0.155	0.000	0.147
VL	0.159	0.153	0.144	0.144	0.147	0.155	0.000

The cause and effect relationship matrix was generated and the result presented in Table 3. D and R represent the sum of the rows and the sum of the columns respectively (see Table 3).

The final evaluation involved establishing the relationship among the cause and the effect criteria. According to the rule-of-thumb, positive ***D-R*** indicated that the criterion belonged to the cause group, while a negative ***D-R*** indicated that the criterion belonged to the effects group (see Table 4). Therefore, UF, UA and DE fell within the cause group, which indicated that they influenced other criteria, while FD, CR, AC and VL fell within the effect group, which meant that they were influenced by other criteria.

D+R indicated how much importance the criteria had and showed the degree of relation between a criterion and all the other criteria. A high value of ***D+R*** meant that the criterion had a high relation with other criteria, while a low value meant that the criterion had a low relation with other criteria. Since ***D+R*** determined the importance of a criterion with respect to other criteria, Table 5 indicated the ranking of the enabling criteria according to importance. The table revealed that “Desirable” criteria constituted the most important enabling criteria followed by the “Usable” criteria, while the “Valuable” criteria were the least important.

Table 3. Cause and effect relationship matrix

Criteria	UF	UA	FD	CR	DE	AC	VL	D
UF	-0.149	0.047	0.026	0.023	0.035	0.042	0.031	0.056
UA	0.044	-0.156	0.042	0.035	0.038	0.032	0.033	0.067
FD	0.030	0.022	-0.141	0.035	0.035	0.033	0.030	0.045
CR	0.027	0.038	0.029	-0.145	0.047	0.022	0.029	0.048
DE	0.016	0.037	0.042	0.046	-0.157	0.047	0.037	0.067
AC	0.042	0.030	0.036	0.040	0.030	-0.151	0.026	0.054
VL	0.043	0.036	0.022	0.022	0.027	0.034	-0.138	0.045
R	0.053	0.053	0.055	0.056	0.056	0.059	0.049	

Table 4. Direct influence of the criteria among themselves

Criteria	D	R	D - R	D + R	Criteria type
UF	0.056	0.053	0.002	0.109	Cause
UA	0.067	0.053	0.014	0.121	Cause
FD	0.045	0.055	-0.011	0.100	Effect
CR	0.048	0.056	-0.008	0.103	Effect
DE	0.067	0.056	0.011	0.123	Cause
AC	0.054	0.059	-0.005	0.113	Effect
VL	0.045	0.049	-0.004	0.095	Effect

Table 5. Ranking of enabling criteria

Criteria	D	R	D - R	D + R
DE	0.067	0.056	0.011	0.123
UA	0.067	0.053	0.014	0.121
AC	0.054	0.059	-0.005	0.113
UF	0.056	0.053	0.002	0.109
CR	0.048	0.056	-0.008	0.103
FD	0.045	0.055	-0.011	0.100
VL	0.045	0.049	-0.004	0.095

5. Discussion

This study has investigated the dyslexic sequence of learning using an Arabic software program to complete three major tasks: Word Recognition, Finding the Missing Piece, Fixing the Missing Piece, and finally Arabic Word Meaning. The software program is called “Eye tracking and chatbot Arabic alphabetic puzzle game application for dyslexics.” The key criteria involved in the app aiding the learning sequence were also examined. The program has been used with dyslexics to help them alleviate their specific learning disability of reading and spelling manifested in individuals experiencing difficulties in word recognition. Even though certain genetic and environmental traits are associated with it (Peterson & Pennington, 2015), there is no common consensus in regard to its ultimate cause (Benfatto et al., 2016). Generally, a correctional approach is being taken, especially through educational and tutoring software programs. This paper has examined the sequence of learning in Arabic text by Saudi Arabian dyslexics using the software program for aiding dyslexics learning approach. Despite the previous studies that evaluate software programs for dyslexics, they did not focus on specific learning processes.

The findings of the research indicated that the longer it took the dyslexic participants to recognize the Arabic word, the more of an error will be established. In all cases were time was measured from identification, puzzling, and interpreting the meanings of the given Arabic words, it could be observed that the participants managed to complete their task within a few seconds. The engagement with the device when running the application took some time, but the tasks involving Arabic word recognition and fixing the Arabic word puzzle were completed within two minutes. Another important aspect of the result involved the longest time taken to find and fix missing puzzle pieces and the “error” that was generated during the experiment. It could be observed that most errors were caused by the eye movements across the small-sized mobile device screen. Thus, the state of visual-spatial attention affected finding the puzzle piece. The error was not quantified, rather it was observed. Each participant’s eye movement was observed in terms of identifying the correct or the wrong puzzle piece. The counted errors were associated with the participants’ inability to find the right pieces. That is, the participants were unable to locate the right puzzle while their eye moved around making decisions, yet the wrong ones. The detailed sequence of the participants' experimental events indicated an improvement of reading abilities as the participants' rate of identifying Arabic words and describing their meanings increased after the preliminary experiment. The participants were able to identify Arabic word correctly within the time limit that was less than the time it had taken them before using the app. They were also able to describe Arabic word meanings accurately within a short period after using the app. Overall, the shortest time recorded in describing the meaning of Arabic word was two seconds and achieved by the majority of the participants.

The connection between this research finding and previous work lies with the fact that the potential utility of recording children's eye movements during reading when conducting future applied research is "repeated overt observation" (Rayner, 2011). That is why this study performed such experiments. The finding revealed the frequencies of Arabic word recognition for dyslexic children. The time taken to find and fix Arabic word puzzle pieces has been drawn. The time taken for revealing the meaning of the Arabic word affect eye-movement was recorded. These records are obtained during the reading. Subsequently it was uses to determine the impact of Dyslexics reading capabilities. Arabic word affects eye-movement when reading and subsequently determine the impact of Dyslexics reading capabilities. Considering the experimental finding on Identifying Arabic Words, Using the Puzzle Piece for Matching Arabic Words and Describing the Meaning of the word or sentence formed, major implications of the research with regard to software applications for aiding dyslexics could be found. The central significance of the study involves the serial position effect in any software program for aiding dyslexics. This study has contributed in establishing a sequence of interaction with a software program for dyslexics. The experimental outcome shows an increase in reading skills that allowed the users to remember what had been learnt first and the sequence of the events until the last event that was learnt in a series.

This paper has also investigated the key attribute of the dyslexic app that influences all other criteria responsible for providing appropriate user interaction. Morveille's user experience design factors were used. According to the analysis of the ranking of the enabling criteria based on importance, "Desirable" was the most important group of criteria with the highest score. Morveille (2004) described "desirability" as a factor of user experience design to mean the how much that app displays an "emotional" design to include aesthetics that conveyed through branding identity. The major aspect of "Desirable" criteria is to express how design elements are used within a given app to evoke emotion and appreciation. This finding is directly concerned with visual-spatial attention meaning to direct attention to the location of what should be learnt during reading within the app that is evaluated. Since it is concerned with what the app displays, it is also tied with how users engage and interact with the app. Therefore, visual-spatial attention is found to influence reading abilities (Gabrieli & Norton, 2012).

6. Research limitations and suggestions for future studies

Although this study was designed to address the research problem as accurately as possible, the results and findings should be interpreted in light of the inherent limitations. Specifically, the study relies on Rayner et al. (2013) findings on children's eye movements during reading and the use of user's experience attributes developed by Morville (2004). The used of key-informant procedure involves children and parents. Both participated in the reconnaissance experiment and final experiment. Even though experimental test for ethnographic and DEMATEL method did not indicate the presence of method bias, it is recommended that future research should consider other forms of minimizing the bias through the use of multiple respondents where the source of answering will involve reliability and validity test. One way to overcome this limitation is by using objective measures. Another apparent constrain of this research is the nature of the experimental evaluation. While the findings of this study may be beneficial in understanding the nature of the dyslexics use of software program, the findings may also be validated by a different approach other than ethnographic experiment and DEMATEL evaluation. Thus, future studies may incorporate the use other experimental evaluation to overcome the shortcoming caused by the ethnographic evaluation.

7. Conclusion

This paper presents a study to understand the dyslexic sequence of learning in Arabic text on an Arabic alphabetic puzzle app for dyslexics. In general, dyslexics face difficulties in learning to read and studying with a tutoring app to reduce their difficulties. The nature of learning through special software programs has not been the focus of past research, especially the sequence of learning interaction with those software programs. This study has outlined Arabic Word Recognition, Sequence of Finding and Fixing Puzzle Pieces, and Ability to Describe the Meaning of Words. An experimental evaluation of the interaction with the software program for dyslexics with 42 participants revealed the rate at with these three sequences of learning with and without using the software program for dyslexics. A decision-making analysis experiment was carried out in order to determine the key interaction aspect of user experience on the Arabic alphabetic puzzle app for dyslexics. “Desirability” has been identified as the key group criteria responsible for interaction with Arabic alphabetic puzzle app for dyslexics and its impact on visual-spatial attention and acceleration of word recognition and determination of their meaning for Arabic-speaking dyslexics. Even though there were quite a number of errors during the experiments by the participants. The study also determined the time it takes for the Arabic word recognition and the description of the meaning of words to the highest degree of accuracy. This study has contributed to improving the understanding of the interaction sequence of software programs for providing solutions to the learning problems of dyslexics.

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