Journal of Engg. Research Vol. 7 No. (1) March 2019 pp. 1 - 11

Adaptive Arabic application for enhancing short-term memory of Dyslexic children

Noura Al-Ghurair and Ghada Alnaqi

Kuwait Institute for Scientific Research, Kuwait
Corresponding author: nghurair@kisr.edu.kw

ABSTRACT

Dyslexia is defined according to the U.S. National Institute of Health as "a learning disability that can hinder a person's ability to read, write, spell, and sometimes speak". In Kuwait, Dyslexia is considered to be one of the most common learning disabilities experienced and diagnosed in school age children. Worldwide research is being conducted to explore the effect of using technology as a positive intervening factor enabling the enhancement of the abilities of dyslexic children. Several institutions are conducting research on how to enhance dyslexic abilities in the context of the Kuwaiti Arabic culture. Kuwait Institute for Scientific Research (KISR) has developed an Arabic application called "Sinbad and Jasmin" in collaboration with the Kuwait Dyslexia Association (KDA). In this paper, we will discuss the design, methodology and evaluation of the developed application, whose aim is to enhance the short-term memory of dyslexic children. Analysis of results of the study conducted on selected dyslexic students from the KDA is presented. An assessment of the long term enhancement effect of the developed application on dyslexic conditions will be conducted in the future.

Keywords: Application development; Dyslexia; Kuwait Dyslexia association; short-term memory.

INTRODUCTION AND BACKGROUND

In 1881, reading disability was first identified by Berkhan (1917) and was known as word blindness. Later in 1887, Rudolf Berlin (Wagner, 1973) introduced the term dyslexia. Dyslexia is the brain impairment in translating received images of written text into an understandable language (Dyslexia, 2015). In this paper we are interested in one of several causes of dyslexia, namely the one caused by limited short-term memory. Short-term memory is defined as 'primary' or 'active memory'. It is responsible for holding a small amount of information in mind in an active, readily available state for a short period of time (Dyslexia, 2015). According to the latest statistics announced by the International dyslexia associations, 15-20% of the world population has a language-based learning disability of some sort, of which 70-80% are dyslexic.

In Kuwait, according to a study carried out by the Kuwait Dyslexia Association (KDA), 6.29% of students enrolled in government schools are dyslexic (i.e. around 30,000 students). Dyslexia is regarded as one of most common learning disabilities in Kuwait. Research has proven that using technology and computer-based training; we can improve reading abilities of dyslexic children especially if it is introduced at an early age. The use of information and communication technologies (ICT) in the interventions to help dyslexic people is becoming more acceptable and has proven to be efficient and useful. Unfortunately, a limited number of computer-based applications to enhance short-term memory of dyslexic children are available in Arabic language. Only few of these applications are adapted to the Kuwaiti culture and context. Hence, there is a need to develop a computer-based application that is well-suited to the Kuwaiti culture.

Skiada et al. (2014) describe a mobile application called Easy Lexia as an intervention to help children with learning difficulties. Assessment results show that appropriate and timely interventions using mobile learning tools are beneficial for children with learning difficulties. Many studies have found that embedding playful and fun game-like exercises engage dyslexic children and produce good benefits (Prensky, 2003; Papert, 2008). Al-Wabil et al. (2010) introduce a multimedia educational game called Memory Challenge to help children with learning difficulties.

Using the game, children will learn strategies for memory, allowing them to develop their cognitive skills. Children participating in the trial were involved along with domain specialists and practitioners in the game design process. Van der Leij (2013) describes the benefits of early interventions aiming at children with familial risk of dyslexia. It is also recommended that interventions be for longer time and should supplement formal reading instruction in the classroom. There are many ways to reduce the difficulties in learning by adjusting the teaching methods to meet the dyslexic needs. Computer-based memory training strategies consisting of rehearsal and visualization have shown some effectiveness in improving dyslexic children's working memory (Van Dall & Reitsma, 2000).

Dyslexic children have problems with auditory, phonological and visual processing, reading and comprehension, memory recall, structure and sequencing, and planning and organization. In our work, we concentrate on the memory recall problem. The short-term memory of a dyslexic person is commonly accessed using tasks that require the immediate recall of information (Rello, 2014). Problems with short term and working memory, in addition to problems with structure and sequencing can impact greatly the accessibility of information and its architecture. Hence, the learning capabilities are affected (Ball, 2006; Petrie & Bevan, 2009; Poobrasert, 2009; Rainger, 2003). Enhancing the graphical presentation, content, navigation mechanisms and information structure and architecture will improve the accessibility of published electronic documents. Guidelines on how to enhance these elements are described in Zhang & Adipat (2005). Consequently helping dyslexic children with short-term memory will increase the usability and accessibility of web content, and hence their learning capabilities.

Memory Booster is an English computer-based application that deploys several strategies to enhance short-term memory using an amusing game style adventure (Leedale et al., 2004). Studies showed that Memory Booster can enhance the short-term memory of children aged 6-7 years old (Thompson & Holmes, 2008). Research showed that using memory training strategies can improve individual›s short-term memory. Luz Rello introduced a method to design reinforcement word exercises to support children with dyslexia using memory enhancement strategies (Rello, 2014). According to Rello, the application of the used memory strategies has shown developmental increases in working memory. Moreover, due to the success of the Memory Booster application being used in KDA Center to train and enhance dyslexic children, KDA specialists have prepared an adapted Arabic content to be understood by Kuwaiti children at a young age. Due to the lack of Kuwaiti standards of common phrases per age group, listing phrases that are suitable for Kuwaiti children aged 4-6 was one of the major research factors in designing this application. The proposed method considers the linguistic patterns in the mistakes made by dyslexic people. The exercise design involves six stages: the exercise type, word selection, word modification, selection of the distractors, difficulty level, and text layout. The method has been also implemented in a mobile application called Dyseggxia. This method allows the personalization of the exercise to suit individual dyslexic learner.

The rest of the paper is organized as follows. Section two provides an overall description of the application and the driving principles. Section three provides a detailed description of the software methodology, processes and tools used. Section four provides some results reporting on the evaluation of the software and its usability. Finally, summary and concluding remarks are provided in Section 5

OVERALL APPLICATION DESCRIPTION

One of the main principles driving the design of our application was the development of a highly accessible application that suits the learning style of dyslexic children. As a result, children using this application are expected to have an increased benefit in terms of short-term memory improvement. Our application was developed based on speech and language therapist's experiences and accessibility and usability research results. We wanted to make sure that the assessment of improvement is not affected by the accessibility and usability of the application it self. Improvements in short-term memory tasks have been realized, when dyslexic participants are engaged in one of the following strategies and practices: rehearsal, visual imagery, creating stories, grouping of items, and organization of information by chunking. In addition, working memory tasks involving both processing and storage have been improved using these memory training strategies. Rehearsal involves the simple repetition of verbal information. Visual imagery involves creating pictures to represent information to be remembered. Creating stories involves generating a narrative that links together

information. Grouping involves using higher-order conceptual categories to group items together. Finally, chunking involves breaking large information into smaller pieces to make it easier to recall or remember.

Based on the principles described earlier, we designed the application, Sinbad and Jasmin, for short-term memory enhancement, to be used by 4 to 6 year-old dyslexic children. A story theme of an Arabic sailorman, Sinbad, was chosen. In this animated story, Sinbad with his friend Jasmin were on a trip. Then suddenly a storm started and their ship sunk. Luckily, they escape and reach an island, where they find an old man. The old man tells them that in order to build their ship again they have to answer a sequence of questions. There are three stages in the application that must be completed in order to reach the end of the questions and build the ship again. Each stageis composed of 12 questions, in which the user is prompted with certain items. Then, a pre-set time delay elapses before displaying images. The user should select the correctimages,that he/she was prompted with verbally before,within a given time. At the end of each stage part of the ship is built. After successfully completing the three stages, a performance certificate is produced for the user. In memorizing the prompted items, the user is instructed by his trainer to make use of the five strategies.

Also, before starting the game, the examiner creates a user record and adjusts the settings according to the dyslexic assessment. So again when starting the game, the user is given a simple Arabic pre-recorded audio sentence to pick up few items. These audio sentences were recorded under the supervision of the KDA specialist. The number of items, which were designed by specialists in KDA, increases as the user progresses. Then, a delay using a pre-set timer will elapse before the images of those spoken items are displayed. The user is instructed to use one of the memorization strategies during the delay period, such as repeating or making silly stories, to keep remembering the prompted items in the order they were said. Once items are displayed, the user should select only the prompted items in a specified time, otherwise the user is moved to the next question. Since young age users were considered when the application was developed, and to overcome any difficulties with the used fonts, all written instructions were also made available as audio instructions and labeled buttons.

APPLICATION DEVELOPMENT METHODOLOGY

The developed application is supported by a database and an automatic performance reporting system as shown in Figure 1.

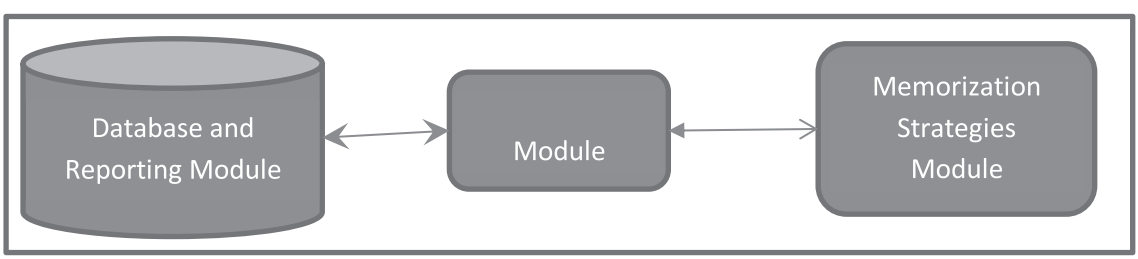

Fig. 1. Main modules of the developed application

The Questions module implements the front end of the application, whereas, the memorization strategies module and the database and reporting module supports the back end. In the next section, we provide more details on the methodology used to develop the front and back end modules.

The application was developed following a typical phased software engineering methodology (Saleh, 2009). In the following, we describe the processes involved in performing each phase.

Phase I: Prototypedrequirements and specifications

In this phase, all desired requirements and specifications including the desired flow of screens, and screen contents and aesthetics were elicited with specialists from the KDA. Several meetings were held, and many iterations of prototypes were used to capture and finalize the requirements and interface specifications. The software tools used are the MS Visual Basic.NET 2008 as the compiler to build the application, and MS Access for database development.

Adobe Flash was used for developing the animations, and Adobe Illustrator and Wave Pad were used as image and sound editing tools.

Professional artists were consulted to develop the desired images using Adobe illustrator using simplified colors (since some of dyslexics can be visually sensitive to colors) and a transparent background. A sound studio was used to record and narrate all the desired sound files under the supervision of an Arabic language specialist from the KDA. The Wave Pad sound editing tool was used and the edited sound files were then indexed in the software.

Several meetings were held with the KDA specialists to elicit the desired application requirements and specifications. These included, among other things, the choice of background colors, number of elements per screen, the screen flow, distribution of elements on the screen, and most importantly the approved images representing the questions. Narrations and questions were recorded in a professional sound studio under the supervision of KDA specialists. A software prototype was developed to make it easy for the KDA staff to visualize and explain their requirements. The prototype was presented, and comments and feedback from specialists were collected. Once all software requirements were clear and approved by the KDA specialists, the software project team proceeded to the next phase of the software development and implementations.

Phase II. Software design, development and implementation

In this phase, the software modules were designed, implemented and tested. MS Visual Basic.NET 2008 was used to develop the main infrastructure and user interface. Samples of the developed graphical user interface (GUI) screens are shown in Figure 2.

Fig. 2. GUI Screens

The developed interface was approved by KDA specialists. The screens can be further subdivided into two main categories, namely, database-related screens and questions and settings screens. The database-related screens include user and examiner data manipulation screens that are used to interface with the database. These screens provide options for various functions as required by the user and examiner, such as adding new entries to the database and editing, and deleting existing data. Note that some of the examiners can be tagged as administrators, which give them the privilege to add, edit, and delete examiners information.Samples of these screens are shown in Figure 3.

a Examiner information database b. Examiner/Trainee selection screenc. Trainee information

Fig. 3. Data manipulation screens

The front end of this application is embedded in the Questions module. There are three different complexity levels: A, B and C. Levels A and B display images in 3x3 mesh, whereas level C uses 4x4 mesh size. Choosing the complexity level depends on the user's dyslexic assessment test. It is worth mentioning that, the user must go through an assessment to determine his/her own dyslexia level in order to set the software parameters. Other parameters include the time between requesting-displaying images and the time of displaying images. Due to the young age of users, all buttons are supported with narrated sound files.

The questions and setting screens include screens for displaying questions and for setting personalized parameters. In the setting screen shown in Figure 4, the user can adapt the software to his capabilities, such as the level and other user preferences.

Fig. 4. Setting screens

The questions screen is used to display questions and are used to navigate the application by the user. The software includes two main screens to display the questions depending on the chosen level of the user, i.e. either 3x3 or 4x4 mesh of images. Figure 5 shows the 3x3 mesh of images.

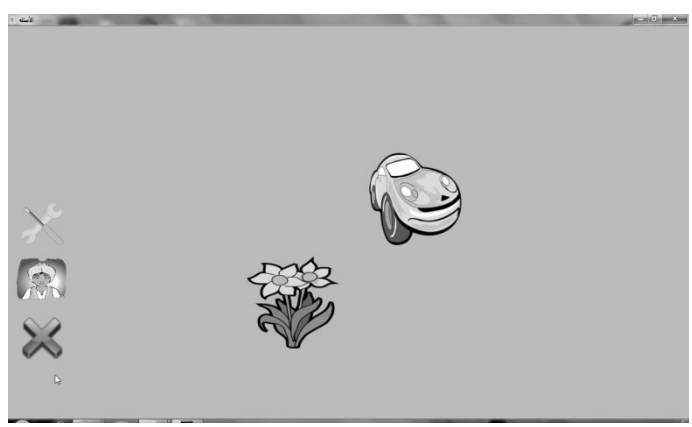

Fig. 5. Questions screen showing the 3x3 mesh images

Adobe Flash was used to create several animated movies such as journey of the Arabic sailor Sinbad, five short-term memory enhancement strategies illustrated with examples, and ending close-up story of Sinbad sailing back home. State-of-the-art techniques were used to incorporate the narration sound files and sound effect files in the animation. Samples of these screens are shown in Figure 6.

a Main strategies screen. b. Demonstration of strategy c. Another demonstration ofstrategy

Fig. 6. Animated screens

The code behind the questions screen is the main code in the entire application, where all the settings and personal information is incorporated from previous screens. Then, questions are formulated and displayed. A randomization routine was developed and used to place images of each question in different randomly generated locations on the mesh each time the program is run. Another timer is invoked after images are displayed. The Next question module is invoked either when the timer expires or after the user responds. The control structure of the module code is described in the flowchart shown in Figure 7.

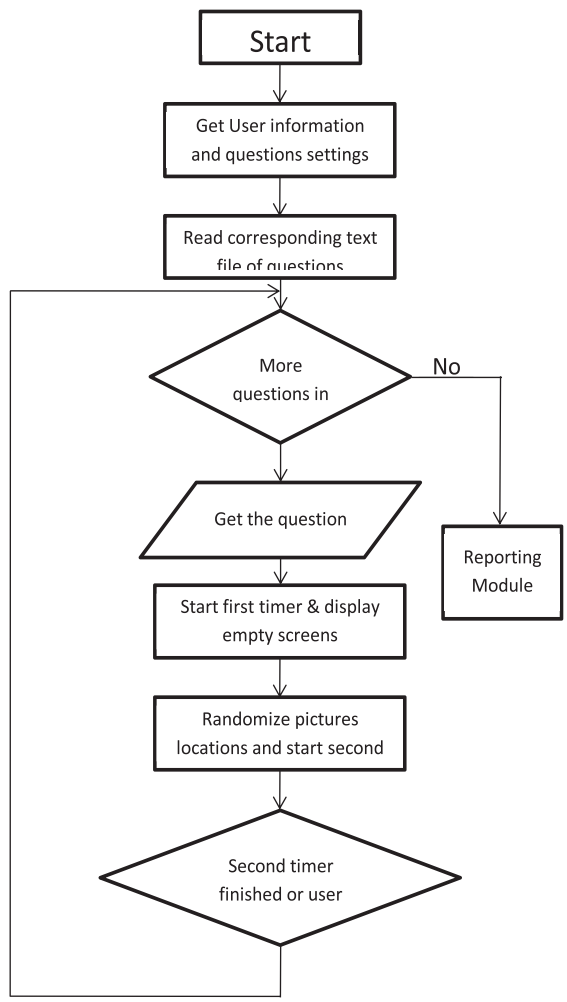

Fig. 7. Questions module flowchart

MS Access is used as a database development tool to ensure compatibility with existing systems at KDA. Figure8 shows the database design including the relational tables and their schemas. The database consists of several interrelated tables representing users' information, session's details and examiners information. The design of the database went through several iterations and modifications, especially during the design and implementation of the reporting software module. KDA specialists requested that the time taken for each mouse click of the user be recorded. Since this will result in a massive amount of data that cannot be accommodated in the database, the developers decided to create a text file for each user and store this information in a 3x3 matrix. Information is extracted from the database and displayed in three levels of detailed reports supported by bar charts.

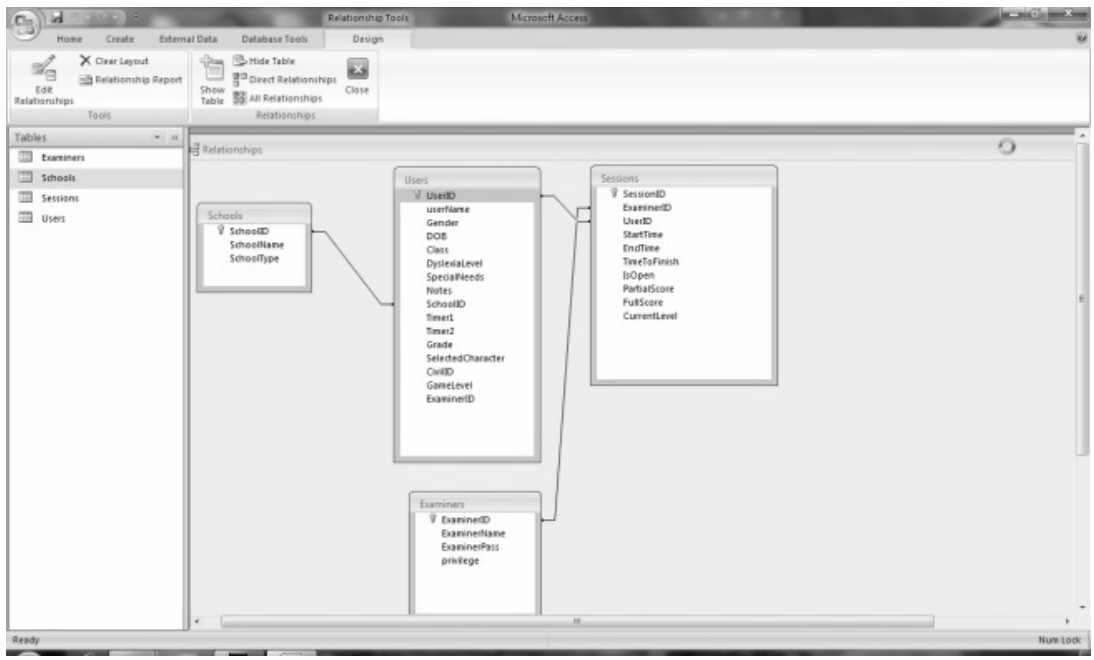

Fig. 8. Relational database design

Figure 9 shows samples of the outputs of the reporting system where it is supported with bar chart graphs.

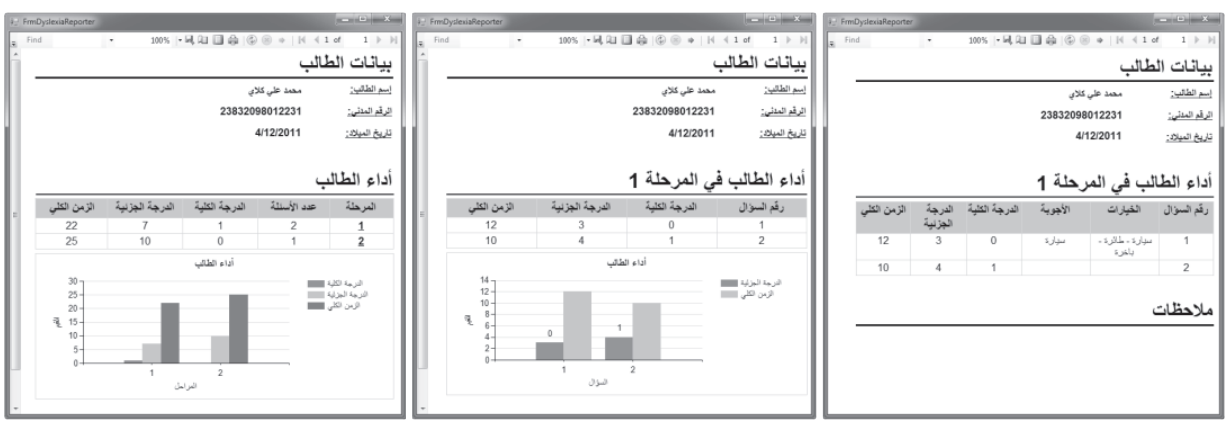

Fig. 9. Reporting

SOFTWARE ASSESSMENT AND EVALUATION

There are two research aspects and outcomes that we would like to assess and evaluate. First, we would like to assess the software usability and accessibility, and second, the effect of using the developed application related to accomplishing the aim of developing such application, i.e. enhancing the short-term memory of dyslexic children. A usability study was conducted on a selected group of dyslexic students at KDA to check several aspects of the human computer interface (HCI) such as: simplicity, user satisfaction, performance, efficiency and learnability. To ensure the validity of the usability tests, users were selected such that they cover different levels of dyslexia. Teachers were absent during the sessions, and users never tried the application before.To accomplish this task, the problem of finding cases, who are dyslexic in the schools of the Ministry of education (MOE) arose. To test the developed application in the ministry of education schools, student must be tested intensively to diagnose dyslexic cases and their degrees of dyslexia must be recognized. Once this information is available, the developed application can be tested on them as a training and enhancing tool. We found that this process will take long time. To overcome this problem, KDA specialists suggested to apply the developed application on several cases being treated in the association premises. KDA developed an intervention study using our application (KDA, 2014). Twenty one 8-year old children of different levels of dyslexia participated in this study and three therapists from KDA were involved in their evaluation.

Usability of the application was assessed by KDA specialists by observing how the children interacted with the system and the way they used the application to boost their short term memory. Also, users were polled about their opinion on the application after they have used it. A laptop with an external mouse was used during the study. Although users are trained on five different memorization strategies, the KDA specialists created a profile for all the users who participated in the study. Before starting to use the application, a video explaining how the application works was presented to the children. Three games were provided to the users in between the phases of the application. KDA specialists observed that these games were very useful in keeping the users' attention and stimulate their minds. KDA specialists also observed that most users used the repetition strategy for memorizing the requested phrases during the waiting period. One at a time, users were asked to use the application and experience two of the three levels of the application, since the aim was only to check usability and not the performance of the users. Although all users attended an information technology class at school, nineteen users faced difficulties in using the mouse as it was hard for them to use it.This indicated that school age children in Kuwait find it more appealing to use the iPad, since they are used to touch screens (iPads). This aspect of interactivity has to be considered in future studies conducted on children as it may hinder the application usability. This was due to the fact that their parents at home are not allowing them to use computer, or due to the lack of games on computers, children have limited capabilities in using computer and have no interest in computers.

In the following, we provide a brief description of some quality criteria including the availability, accessibility, portability, appeal, completeness, correctness, clarity and performance of the application. Also, KDA specialist had major contribution to some of these criteria. The application is highly available. It is installed in KDA for children to use and CDs are available for purchase from KDA. Since the application is currently standalone, it is highly available on personal computers and laptops and no network availability is needed. The application is highly accessible and is runnable on the most popular operating platform. In Kuwait, schools and most houses are using MS Windows as the main operating system and the developed application is designed to run on Windows. Most users found the application appealing and attractive to use. 19 users liked their experience with it and wanted to have a copy of it for use at home. The two users, who did not like it said they preferred an action game (like Sony PlayStation). All children found that the requested phrases are familiar and easy to identify. Pictures representing the phrases are clear, familiar and well-representing the phrases. In addition, the recorded sound of phrases was clear and understandable. Users were satisfied with the theme and coloring of the interface. The highlighting used on object selections provided useful feedback to users and met their expectations. Finally, users were able to answer within the pre-set values of timers. Only two users missed a question due to their lack of ability in remembering the phrases. The application was stable and users managed to complete their stage with no difficulties.

KDA reported that the application was well enjoyed by the children and was well received by the therapists. The therapists reported that the system managed to get the children engaged better than traditional paper training. In general, KDA therapists were fully satisfied and they were asked to have an iPad version of the application.

CONCLUSION AND FUTURE WORK

In this paper, we describe a pioneering Arabic computer application to help enhance the learning abilities of dyslexic children by improving their short-term memory. Supported with a database and detailed reporting, the developed software will be a handy tool for the dyslexia specialists to track the improvement in users. The developed software can be easily used by dyslexia centers in the Gulf Cooperation Council (GCC) as well as dyslexia centers in the Arab region. Research shows that m-learning (Paterno, 2002) has a great impact in the education process. We intend to design and develop a tablet version of this application, which is expected to be of high benefit if gesture features are intensively used. Also, KDA specialists and dyslexic users indicated that they prefer to interact with a tablet version of the application. A web-based application can also be developed if needed by the users' community. The reporting system will be enhanced by using a database system to save historical records of student usage to be used for monitoring progress and performing further analysis. In addition, as a future work, several other learning difficulties (LD) need to be supported due to the lack of Arabic computer-based tools to screen, test and treat children with such disabilities. LD plays a major role in the education process and can be easily enhanced with computer-based applications. These computer applications can be developed to highlight and embed best practices for enhancing students' performances.

ACKNOWLEDGEMENTS

Authors are grateful for the financial support received from Kuwait Foundation for the Advancement of Science (KFAS). Authors thank KDA specialists for providing the adapted Arabic content and for their fruitful recommendations. In addition, we gratefully acknowledge the assistance provided by CCET to carry out the usability study.

REFERENCES

Al-Wabil, A., Meldah, E., Al-Suwaidan, A. & AlZahrani, A. 2010. Designing educational games for children with specific learning difficulties: insights from involving children and practitioners. 2010 Fifth International Multi-conference on Computing in the Global Information Technology, IEEE Computer Society, 195–198.

Ball, S. 2006. Accessibility in e-assessment guidelines. Final report commissioned by TechDis for the e-assessment group and accessible e-assessment forum.

Berkhan, O. 1917. Uber die Wortblindheit, ein Stammeln im Sprechen und Schreiben, ein Fehlim Lesen. Neurologisches Centralblatt, 36:914–927.

Dyslexia, 2015. Diseases and Conditions. Mayo Clinic, www.mayoclinic.org.

KDA, 2014. Assessment letter, Private communication.

Leedale, R., Singleton, C. &Thomas, K. 2004. Memory booster: Guide for teachers, parents and professionals. Lucid Innovations Limited.

Papert, S. 1988. Does easy do it? Children, games and learning. Game Developer Magazine, 88.

Paterno, F. 2002. Editor, Human computer interaction with mobile devices. LNCS 2411, Springer.

Petrie, H. & Bevan, N. 2009. The evaluation of accessibility, usability and user experience. The Universal Access Handbook, C Stepanidis (ed), CRC Press.

Poobrasert, O. 2009. Work in progress: a case study of usability testing of software tools for people with learning disabilities. Proceedings of the 5th WSEAS/IASME International Conference on Educational Technologies (EDUTE'09), 157–161.

Prensky, M. 2003. Digital game-based learning. Computers in Entertainment, 1(1):21.

Rainger, P. 2003. A dyslexic perspective on e-content accessibility.TechDis, 19 pages.

Rello, L. 2014. Design of word exercises for children with dyslexia. Procedia Computer Science, 27:74–83.

Saleh, K. 2009. Software Engineering, J. Ross Publishing, USA.

Skiada, R., Soroniati, E., Gardeli, A. & Zissis, D. 2014. Easy Lexia: a mobile application for children with learning difficulties. Procedia Computer Science, 27:218–228.

St Clair-Thompson, H. & Holmes, J. 2008. Improving short-term memory and working memory: methods of memory training, Chapter 4.New Research on Short-Term Memory, Nova Science Publishers.

Wagner, R. 1973. Rudolf Berlin: Originator of the term dyslexia. Annals of Dyslexia, 23(1):57–63.

Van Daal, V. & Reitsma, P. 2000. Computer-assisted learning to read and spell: results from two pilot studies. Journal of Research in Reading, 23(2):181–193.

Van der Leij, A. 2013. Dyslexia and early intervention: what did we learn from the dutch dyslexia programme?. Dyslexia, 19:241–255.

Zhang, D. & B. Adipat, B. 2005. Challenges, methodologies and issues in the usability testing of mobile applications. International Journal of Human Computer Interaction, **18**(3):293–308.

SUBMITTED: 10/01/2016
REVISED : 18/05/2016
ACCEPTED : 20/06/2016

تطبيق العربية على التكيف لتعزيز الذاكرة على المدى القصير من الأطفال المعسرين في القراءة

نورة الغرير و غادة النقي

معهد الكويت للأبحاث العلمية – الكويت

nouralghurair@gmail.com

الخلاصة

وفقا للمعهد القومي الأمريكي للصحة فإن العسر القرائي يعرف على أنه: «صعوبات التعلم التي يمكن أن تعوق قدرة الشخص على القراءة والكتابة والتهجئة وأحيانا الكلام». في الكويت، يعتبر العسر القرائي واحدا من أكثر صعوبات التعلم شيوعا لدى الأطفال في سن المدرسة. عالميًا تجري الأبحاث لمعرفة أثر استخدام التكنولوجيا الحديثة في تعزيز وتطوير قدرات الأطفال المعسرين قرائيًا. وعلى الصعيد المحلي، تدرس العديد من المؤسسات البحثية كيفية تعزيز قدرات المعسرين قرائيًا ضمن إطار اللغة العربية والبيئة الكويتية. وقد طور معهد الكويت للأبحاث العلمية (KISR) تطبيق باللغة العربية بعنوان "سندباد وياسمينة" بالتعاون مع الجمعية الكويتية للديسليكسيا (KDA). في هذه الورقة، سوف نناقش تصميم ومنهجية وتقييم التطبيق والذي يهدف إلى تعزيز الذاكرة قصيرة المدى لدى الأطفال المعسرين قرائيا ". يتم تقديم تحليل أولي لنتائج الدراسة التي أجريت على الطلاب المعسرين قرائيا على شريحة مختارة من الجمعية الكويتية للديسليكسيا. في المستقبل، سيتم إجراء تقييم تأثير استعمال التطبيق على الحالات المعسرة قرائيًا غلى المدى الطويل.