Evaluation of an Educational Game for Children with Dyslexia: FunLexia-A Case Study

Nihal OUHERROU, Fatimaezzahra BENMARRAKCHI, Oussama ELHAMMOUMI, and Jamal EL KAFI

***Abstract*—The use of information and communication technologies (ICTs) in the education of children with learning disabilities is increasing. However, there is a little interest in the appropriate evaluation methods, that should be used to study the effectiveness of these tools, and factors that may impede their adoption in the learning setting. The purpose of this paper is to contribute to the design and evaluation of FunLexia; an educational game developed to help children with dyslexia to learn to read Arabic. The evaluation for FunLexia combined different usability methods, and it is conducted by specialists in the field of special education and children with dyslexia. The outcomes show that the educational game has the potential benefits to help children to learn Arabic. And they suggest features and aspects that need improvements for the next version of the educational game.**

***Index Terms*— Dyslexia, Educational game, Heuristic Evaluation (HE), Information and Communication Technology (ICT), Learning disabilities (LD), usability**

I. INTRODUCTION

LEARNING disabilities (LD) is a general term that covers a wide range of learning difficulties, such as dyslexia, dyscalculia, and dysorthographia. The Learning Disabilities Association of America (LDA) defined learning disabilities as a neurological problem which manifested by a disorder in one or more of psychological process essential to read, spell, think and do mathematical calculations and also other skills such as organization, time planning, long short-term memory, and attention. Dyslexia is one of the most specific learning disabilities, it is characterized by reading difficulties. It refers to children who despite their conventional classroom experience, they fail to attain the language skills of reading, writing and spelling appropriate with their intellectual abilities[1]. According to [2] the prevalence of LD around the worldwide is 15-20% , where dyslexia affects probably 70-80% .

The advancement of information and communication technologies has provided a vast number of tools that have been designed to contribute in the field of special education to assist children with LD in learning. Previous studies had stated that the use of ICT increases and empowers the learning process of target children [3], [4]. Further, [5] pointed out the importance of ICTs to promote the creativity of pupils with specific learning disabilities. In other words, ICTs have the beneficial contribution to differentiated instruction, establishing a creative learning environment and supporting teachers in an inclusive classroom[6]. Besides, [7] found that ICTs use improves LD students' attitude towards learning and provides them with appropriate skills that aid to attain their academic knowledge. However, most current studies in this area don't offer a strong solution that responds to the needs of children with LD, because they don't take into consideration learners' differences such as learning preferences and cognitive capacity. As claimed by [8], [9], learning with technology depends on learner characteristics.

Furthermore, the evaluation of ICTs tools is important to identify problems and improve their performance. Although, enhancing the learning process of children with special needs, cannot be achieved if the tool usability is not appropriate for target children. In this research, we aim to contribute to solving this problem by designing an educational game for children with dyslexia that helps children to learn to read Arabic. Another research goal is to evaluate relevant aspects of the game. In this study, inquiry, experimental and inspection method has been used in the evaluation process.

The rest of this paper is organized as follows. Section 2 presents related work. The design of FunLexia will be given in the section 3. The results of the evaluation are presented in Section 4. Section 5 concludes the paper and outlines future directions.

II. RELATED WORK:

In this section, we first define dyslexia. Then present some ICT tools that aims to enhance learning for children with special needs and methods used to evaluate the effectiveness

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of these tools. Finally, we describe some categories of evaluation methods.

A. Dyslexia:

Dyslexia is a learning disability that affects word recognition in reading and word production in spelling due to a deficit in phonological information processing[10]. The word dyslexia is derived from a Greek word composed of two parts ''dys'', referring to difficulty and, and "lexic", referring to "word or language". Besides , it is estimated that 6% to 17% of the school age population have dyslexia [11]. According to the Speech-Language Pathology service El Jadida-Morocco, over the three years (2013–2014-2015) 517 new patients with speech and language difficulties have been diagnosed, where 54 patients, aged from 6 to 13 years old, are dyslexics which represent 10% of the population of El Jadida city who have dyslexia[12].

The causes of dyslexia have been the subject of intense debate within the scientific community. Dyslexia can be a neurological condition caused by a different wiring of the brain. Recent evidence suggests that there is a convergence on its genetic and neurobiological origin and on its underlying cognitive processes[13]. Brain imagery suggests that there are differences in the temporo-parietooccipital brain regions between dyslexic and nonimpaired readers[14].

There is a different classification of dyslexia. Acquired and developmental dyslexia are the most popular classification in the literature; Acquired dyslexia refers to individuals who were competent in reading, but they lost this ability because of brain injury. While developmental dyslexia refers to individuals who have difficulty in initial reading acquisition[15]. The signs and symptoms of dyslexia differ from person to another, according to Hennigh [16], dyslexics exhibit some common features:

- Reversal of letters in reading and writing;
- Omission of words while reading and writing;
- Difficulty in converting letters into sounds and words;
- Difficulty in using sounds to create words;
- Difficulty in recovering from memory sounds and letters;
- Difficulty in learning the meaning of sounds and letters.

B. Information and communication technology (ICT) and Learning disabilities (LD)

Information and communication technologies (ICTs), have become a part of our daily life and changed the ways of people live, work, play and learn. The integration of ICTs in the field of education seems to have a positive effect to enhance the teaching and learning process. They tend to be a support tool to accelerate, enrich, help, motivate and engage students[17].

Recently, there has been an increasing interest in the potential benefits of ICTs use in special education. A number of studies have provided a great number of assistive e-learning tools to support children with SLD in writing, reading, and math. Among these studies Children's Storybook Reading System (StoBook) using Radio Frequency Identification (RFID) Technology designed by [18] for children with reading difficulties aged between 7-12 years old. It aims to improve reading and provide an interactive learning environment that motivates and allows them to learn while having fun. Children can move their hands, eyes and other body parts to place the syllable-card and pictures during their interaction, which make the learner active. However, the tool requires improvements in term of design and guidelines. It is tested based on comments and feedbacks received from teachers and children. Similarly, SERVI is a special education e-learning environment developed by [19], to support students with reading, writing difficulties, and perspective skills. It is an e-learning environment that provides a graphic interface with specific features large and clear fonts and colors, pictures and speech. SERVI is structured to attract and enhance the students' motivation and autonomy. Its evaluation is conducted by questionnaire in a special vocational school in Finland, Lithuania and Hungary. Nevertheless, the theories and methods used to design SERVI have not been presented.

Other studies have carried out in designing ICT applications to assist children with dyslexia. For instance, Dyslexia Baca is a mobile application developed in Malay language particularly for children with dyslexia [20]. It focused to help children to recognize and distinguish between letters. The design of Dyslexia Baca is based on ADDIE model, learning ecosystem and multisensory. Its effectiveness is evaluated by heuristic evaluation done with multimedia experts. In the same context, AGENT-DYSL is an intelligent system that combines speech recognition, affective state recognition via image recognition, and error type profiling via an adaptive, ontology-driven knowledge core to provide personalized support for the learner which promotes the development of reading skills for children with dyslexia. The evaluation of AGENT-DYSL was conducted by questionnaires with teachers and students. However, the system focuses only on one of dyslexics' difficulties which is reading[21].

Another example of LD is dyscalculia, which is a specific learning difficulty that affects mathematics, or more appropriately, arithmetic skills. KidKanit is a calculating aid tool designed by [22], that improves children with dyscalculia basic skills in mathematic. It integrates all multimedia contents animation and colorful graphics to motivate them to learn. The evaluation is based only on children's comments. In the same context, Calculic kids is a mobile application, was developed to help children with dyscalculia in numerical learning. It focused on number counting, object counting, addition and subtraction. It is developed in Malay language based on children's characteristics. The application was tested with seven dyscalculic children. However, the application interfaces have not been demonstrated[23].

In summary, this section has reviewed many useful tools aiming to assist children with specific learning disabilities. And methods used to evaluate the effectiveness of these tools.

C. Usability Evaluation:

Usability is defined in ISO 9241-11 as "the extent to which a product can be used by specified users to achieve specified

goals with effectiveness, efficiency, and satisfaction in a specified context of use". Usability comprises three aspects. Firstly, the effectiveness refers to the products accuracy and completeness with which users achieve a certain goal. Secondly, the efficiency is the relation between accuracy and completeness, it aims to measure the resources experienced by users to achieve the goal such as effort and the time required. Thirdly, satisfaction is the users' comfort, and the positive attitudes towards the use of the products[24]. Several methods have been used in the literature for evaluating e-learning tools includes cognitive walkthrough, heuristic evaluation, guideline review, interview, observation, and questionnaires[25].

Nielsen differentiated between two main categories of evaluation methods analytic and empirical ones [26].The analytic methods are theoretical models, rules, or standards which stimulate users' behavior. These methods are widely used before the development of prototypes and the participation of users is not required. On the other hand, the empiric methods require the implementation and the development of a product. The participation of representative users and also specialist in usability is necessary. Besides, inquiry, experimental, and inspection methods are the most methods used for usability evaluation in human-computer interaction.

Inquiry methods aim to evaluate the quality of a system by measuring users' opinion. In these methods, experts make direct questions to users about the system. It comprises [27]:

- **Questionnaire:** In this method, users are asked to complete a structured questionnaire that includes a multiple choice of multiple questions about the quality of a system.
- **Interview:** involve that the researcher asks direct question to the users. That are structured from the general opinion about the system to the specific characteristics.

Experimental methods require the observation of end users while performing a task using a system under evaluation. They include[27]:

- **Performance measurement:** It is a classical method of system evaluation; it is based on some criteria such as time to complete a task or number of errors made.
- **Thinking aloud protocol:** This method is based on opinions and feeling expressed by end users while interacting with the system.
- **User logging:** It is a method that requires the record of users 'actions while they interact with the system by using special equipment such as voice recording, video recording, and user logging.

Inspection methods involve evaluators inspect and examine user interface usability. Usability inspectors can be usability experts, software developer or other types of specialists[28]. One of the most suitable inspection methods is heuristic Evaluation (HE) created by Nielsen [29], it helps to identify usability problems in the user interface design. HE is conducted by a small group of evaluators who inspect the interface of the system and verify its conformity with a list of user interface guidelines. There are 10 usability heuristics proposed by[29] (See annex A).

The inquiry, experimental, and inspection methods will be used for usability evaluation of the educational game. Researchers [30]–[32], pointed out the importance of combining different usability methods, they stated that it can be very helpful and powerful to identify the majority of the problem. Besides, the results obtained from using different methods will be feasible and efficient than using a single method

III. Design of FunLexia for children with dyslexia

A. Theoretical foundations of FunLexia

FunLexia is the second version of an educational game developed by[4] to support children with dyslexia Arabic skills in writing, reading, and comprehension. The theoretical foundations of the game are thanks to previous studies done by researchers [33]–[36]. They have been working in investigating children with dyslexia preferred learning styles and the most common errors in Arabic faced by children. Learning styles can be defined as attitudes and behaviors, which define an individual's preferred way of learning[37]. The researchers to consider target children preferred learning styles based on "VAK learning styles"[38] and "Honey and Mumford learning styles"[37]. The results have shown that the majority of target children tend to be visual and activist learners. Besides, researchers conducted other study to identify the most common errors in Arabic faced by learners with dyslexia[36]. The results have shown that Dyslexics children commit the following spelling and writing errors: long and short vowel(a/omission), transposition, letters additions, omitting letters, add words, mix up word, phonological similarities, letters' shape similarities, and syntactical rules. Further, a great number of research theories were taken into consideration in designing the educational game such as Piaget's theory of constructivism[39], the cognitive theory of multimedia learning[40], and the cognitive load theory[41].

B. Funlexia overview:

FunLexia is developed for children with dyslexia aged between eight and twelve years old. The name 'FunLexia' composed of two parts 'Fun' and 'Lexia', which means that the purpose of the educational game is to make learning enjoyable and fun. 'Lexia', refers to 'word' in Greek but in the game is also the name of the character that accompanies the learner in a different stage in the game, and it is presented as a monkey.

the purpose of the educational game is to make learning enjoyable and fun. 'Lexia', refers to 'word' in Greek but in the game is also the name of the character that accompanies the learner in a different stage in the game, and it is presented as a monkey.

The basic idea behind the educational game is to help children to learn to read Arabic. It includes different multimedia contents such as pictures, sounds, video and animation. Also, verbal encouragements in the case of right or wrong answer. For example,'good job'or 'you are doing well' when the response is correct and 'try again'or 'try more'in the case of

incorrect answer in order to encourage children. It uses a number of stars that light up to inform the child about his/her progress. The duration needed to complete the game is between 10-15 min, but in this version the time to accomplish tasks is not limited for children[42].

Besides, it includes a set of tasks. The game is built around the theme of treasure island. And it is composed by serval islands. These islands are organized in three major activities, pretest, and posttest. Each island provides different learning activities in a different setting. The child is invited to click on the map icon marker to start the activity, when the child completed the activity the boat moves to the next island until the end of the game (see fig.1).

Fig. 1. The home page of FunLexia

The Fig.2 shows the screenshot for ‘I listen and I build’ activity. In this activity, the child is invited to listen to the word and drag and drop letters in the right place to construct the word. Letters are randomly distributed. And they are accompanied with the picture of the word to increase attention span. we focused on some Arabic errors such as phonological similarities (س,ص) (ض,ظ) and letters’ shape similarities (,ش س)(ح, ج, خ) and (ط,ظ). The main goal of this activity is to improve children reading skills

Fig. 2. 'I listen and I build' activity

The fig. 3 shows the screenshot of ‘I build and I complete ‘activity. It is a puzzle the child is invited to use pieces to construct the picture. Then, choose the correct written word. In this activity we focused on phonological similarities (ض, د) and letters’ shape similarities (ر,ز), (ف,ق) and long vowel (add/omission) such as (ا,ي). This activity tends to enhance children writing skills.

Fig. 3.'I build and I complete' activity

The screenshot of 'I listen and I complete' activity is showed in the fig.4, the child is invited to complete the sentence’s missing letters from the list. The principal goal of this activity is to develop children short term memory and concentration. It focused on long and short vowels (ا, ي, و) and (ـّـ).

Fig. 4. 'I listen and I complete ‘activity

IV. Evaluation of Funlexia:

The evaluation For FunLexia, combined three different usability categories; inspection experimental and inquiry methods. For the inspection methods, Nielsen Usability Heuristics has been employed. In the experimental method, we used performance measurement, the thinking aloud protocol and user logging methods. For the inquiry methods, an interview was used. In this section we present the participant and procedure used of each method and results.

A. The Heuristic evaluation of FunLexia:

- ***Participant:***

Heuristic evaluation involves a small group of evaluators that examine and identify any problems with the design of user interface. Nielsen recommends between three and five evaluators [43]. The present study was done by three evaluators, specialists in the field of special education and usability expert. They were selected based on their experience on usability and ICT use in special education.

- ***Procedure and Materials:***

In order to perform the heuristic evaluation of FunLexia, we followed a simple process that starts with the presentation of the game interfaces that will be evaluated. In the first step, the evaluators navigate freely to obtain a general scope of the educational game interaction. In the second step, the evaluators realize again another navigation, investigate different game elements and compare them with a list of sets of heuristics are based on Nielsen's original ten heuristics.

After trying each interface one by one, they were asked to answer with No or Yes, rate the severity of the problem using Nielsen's severity scale[44] from 0 to 4 and write a comment or recommendation if they had. The result from the heuristic evaluation is presented and discussed together with the feedback from evaluators in the TABLE I.

Severity of the problem:

0: No identified problem
1: Cosmetic problem, change suggested but not necessary
2: Minor problem, change recommended with low priority
3: Major problem, change recommended with high priority
4: Catastrophe problem, it should be fixed

- ***Results and discussion:***

TABLE I
FUNLEXIA HEURISTIC EVALUATION RESULTS

	Proposed Heuristic evaluation for FunLexia	Yes	No	Severity of the problem	Comments	Recommendations
UH1	The educational game keeps users informed about what is going on.	☒		0	▪ The educational game should inform children about any change in the game status.	Use an appropriate feedback with a clear message, to inform children about the interface they are currently on, and also the next action.
	At the end of each activity, the feedback indicates the next action.		☒	3		
	The educational game informs target users their progress during performing task.	☒		0		
	Response times are appropriate to the task.	☒		0		
UH2	The educational game speaks the user's language.	☒		0	▪ The educational game provides a good match between system and real world.	---
	The educational game uses familiar icons.	☒		0		
	Follows real-word conventions.	☒		0		
	Tasks appear in a logical order.	☒		0		
UH3	The educational game support undo and redo.		☒	3	▪ The absence of undo/redo in the game.	Support undo/redo through 'cancel button', 'back button'.
	The educational game permit target users to control their actions.		☒	2	▪ The game doesn't allow users to move freely as they wish.	
	User can go back to previous task.		☒	4	▪ Children cannot back to previous task.	---
UH4	The place of component on each interface expresses the same thing.	☒		0	▪ All components on each interface are consistent.	
UH5	The educational game is carefully designed to prevent a problem from occurring in the first place.	☒		0	▪ The game prevents children about errors.	
UH6	Minimize the user's memory load.	☒		0	▪ The education game promotes recognition and recall, through visibility of objects.	---
	Objects, actions, and options are visible.	☒		0		
	Appropriate color contrast	☒		0		

	between images, elements, and text.				▪ The font style used in text is visible and appropriate for children with dyslexia.	
UH7	The educational game program speeds up the interaction for the expert user, but also to respond to the needs of the inexperienced child.	☒		0	▪ The game is flexible to use.	---
UH8	The educational game interfaces don't contain information which is irrelevant or rarely needed.	☒		0	▪ All the information presented in the game are relevant.	---
UH9	Error message is used in sound format to indicate error.	☒			▪ Error message does not provide help to children, it does not propose the cause of the wrong answer and does not indicate the solution.	Use a clear error message, that help children to overcome difficulties during interaction.
	The error message proposes the cause of the wrong answer.		☒	4		
	The error message indicates the solution.		☒	4		
UH10	The educational game provides help to users.	☒		0	▪ The help function is presented on each game interface.	---
	The educational game makes the information easy to search, focused on the user's task.	☒		0		

The main goal of this current study was to perform the heuristic evaluation to identify any problems in the interface design of FunLexia. The TABLE I above shows a summarized the major positives areas of the game interface and also the major areas that need improvements. In the following paragraph evaluation of each interface heuristic rule are presented and discussed.

1. Visibility of system status (UH1):

The evaluators found that the educational game informs children about what is going on. For instance, the game uses feedbacks when the child makes wrong or right answer. And a number of stars that light up to inform target user about his/her progress during performing a task. However, the educational game requires improvements in term of appropriate feedback. For instance, the first page that appears when the child executes the game is the home page. The absence of feedback in this page to inform the child about his/her position may create a feeling of confusion and disorientation. Also, at the end of each task, the appropriate feedback is necessary to inform the child about the next action. It is one of the most key strategies associated with the game world design, it offers support on the learning process and enhances motivation. In the game-based learning context, feedback is necessary for improvement and success. As stated by [31], feedback "allows the player to determine the gap between the current stage of knowledge and the knowledge required for ultimate completion of the game's task". Besides, [46]highlighted the importance of feedback in the interactive learning environment for children with special needs, to ensure active way of learning and improve the level of self-acting and self-concentration.

2. Match between system and real world (UH2):

The educational game uses Arabic the users' language, and it uses words, concepts, and sentences familiar to target users. Further, it follows real-world conventions. Thus, the educational game screen is clear and easy to understand, the order of content is reasonable. And the information is presented clearly. Hence, evaluators have not mentioned any usability problem in this usability heuristic rule.

3. User control and freedom (UH3):

In this usability heuristic, evaluators found that there is a lack of navigational buttons in the educational game interfaces. It does not allow target user to navigate freely and performs actions as he/she wishes. For instance, once the child starts an activity, then he/she cannot return to the previous page if he/she forgets to answer to a question or accidentally click to the next button.[47]point out that providing users control over elements of the game, empower the gaming experience and make the learning activity more engaging and productive. Especially, children with LD need to feel autonomous about their action. The evaluators indicated a priority level and further attention is needed to fix the problem.

4. Consistency and standards (UH4):

The educational game components are consistent and expresses the same thing. It ensures visual consistency within design elements and between the game interfaces such as layout, colors, icons, navigation, and backgrounds. Furthermore, the clickable items are placed in the same place on each interface. Therefore, no problem discovered from evaluators.

5. Error prevention (UH5):

The educational game is carefully designed, to prevent children in the case of errors in the first place. Therefore, evaluators have not identified any usability problem in this usability heuristic rule.

6. Recognition rather than recall (UH6):

Relevant information is visible to minimize the child's memory load. In general, all objects, actions, and options are visible. The educational game structure is clear, pictures, sounds, and animation are arranged appropriately. The visual aid is visible. The game design is attractive, appropriate color contrast between images, elements, and text. Furthermore, specialists in the field of special education emphasis the importance in which text is presented for children with dyslexia. And they say that the text has been well written and produced. Thus, no problem detected by evaluators.

7. Flexibility and efficiency of use (UH7):

The evaluators found that the educational game does not show flexibility and efficiency problems. The educational game is flexible to use by both experienced and unexperienced user.

8. Aesthetic and minimalist design (UH8):

The game interfaces don't contain information, which is irrelevant or rarely needed to use. Evaluators point out that the game context matches the learning context. Further, pictures, text, animation, sounds, and language used in the game are suitable to target children. And the learning goals of each activity are clearly presented.

9. Help users recognize, diagnose and recover from errors (UH9):

The evaluators found a problem in error message with a high priority. They indicated that FunLexia used only error messages in sound format to indicate the errors. However, there is no clear warning message that prevents children's error. Besides, the error message should be informative, expresses in clear language, precisely indicate the current problem and help the child to solve the problem.

10. Help and documentation (UH10):

The educational game is designed to provide help for target children. It uses a short video that explains further instructions to follow while performing the game. And the help function is presented on each game interface.

B. Experimental method:

- ***Participant:***

In this study eleven children with dyslexia aged between 8-12 years old, are participated in the evaluation of FunLexia. They were selected from the Speech-Language Pathology Service-Health, El Jadida Morocco.

- ***Materials and procedure:***

In the current study, we used Camtasia Studio's Screen Recorder to record children interactions with the Game.The evaluation measures that were collected are the following:

1. The time expended by children to perform different activities proposed by the game.
2. The difficulties faced by children during interaction.
3. Children 's opinion and comments while playing the educational game.

- ***Results and discussion:***

The TABLE II shows the results of three activities for the FunLexia, the accomplishment of tasks is noted with complete (C), Complete with help (CH), Incomplete (IN).

TABLE II
EXPERIMENTAL METHOD RESULTS

Children	Activities			Time expended in the educational game	Children 's opinion and comments While performing the game	Difficulties faced by children
	1	2	3			
Child.1	C	C	CH	16 min	▪ "I like the colorful graphics" ▪ "The puzzle activity is fun"	----
Child.2	CH	CH	IN	31 min	▪ ''The activity 3 is hard for me, I cannot do it''	The child does not know how to start the activity and has a difficulty to drag short and long vowels to complete the sentences missing letters in the activity 3.
Child.3	C	CH	CH	13 min	▪ "I forgot to answer to a question, can I go back to previous page"	Problem in navigation, the child cannot go back to previous page.
Child.4	CH	C	CH	16 min	▪ "I like the game world"	----
Child.5	C	C	CH	12 min	▪ "I like the puzzle activity"	----
Child.6	C	C	C	16 min	▪ "It is very enjoyable"	----
Child.7	C	C	CH	18 min	▪ "I want to win the treasure at the end"	----
Child.8	C	C	IN	26 min	▪ "I like the game sounds and animation" ▪ ''The activity 3 is very	The child feels lost sometimes on which interface he is currently on

					difficult''	and he does not know how to use the help function.
Child.9	C	C	CH	14 min	▪ ''The boat that moves on each island is amazing''	The child cannot cancel an action, when he mades an error.
Child.10	C	CH	CH	20 min	▪ "learning by using game is enjoyable"	The child does not know how to exit the application.
Child.11	C	C	CH	16 min	----	----

The experimental methods results revealed that nine children accomplish all game activities. Whereas two children failed to accomplish all tasks, they stopped in the activity 3 because they found it difficult. During the interaction with FunLexia most of target children listen to instructions before completing tasks and they use help function, when they face some problems while completing their tasks. One of them, couldn't surmount the difficulties he/she face despite listening to instructions, because he/she does not understand them clearly. Other child does not know how to use the help function.

The duration needed to complete the game activities is between 10 min and 15 min. As noticed, the time expended to perform the game differs from one child to another. The child 2, 8, 10 spend extra time in the game compared to other children. It seems that the period needed to accomplish all activities depends on child characteristics and task difficulty. Besides, the recording of children's opinion during their interaction have shown that the most children have a good attitude toward the use of FunLexia to learn to read Arabic. Further, they find the game enjoyable and Fun. And they like the game elements and content. However, children face some problems, for instance they cannot go back to previous page and they feel lost sometimes. Thus, the educational game requires improvement in terms of navigation, feedbacks.

In sum, the thinking aloud protocol may not provide a sufficient feedback from users about the game. For this reason, we conducted an interview with children and speech therapists. The next section the results obtained from an interview session will be discussed.

C. Inquiry method:

- ***Participant:***

An interview was conducted with eleven children and two speech therapists. The interview session took place in the Speech-Language Pathology Service-Health, El Jadida Morocco.

- ***Procedure and Materials:***

After performing the game each participant was interviewed in a quiet room. Besides, participants were asked to answer to an interview consisting of five questions. The first question is an open question aiming to determine participants' opinions about the educational game. The second question used to obtain more information regarding the most things liked by target users in the game. The third and fourth questions were used to determine the most preferred and difficult activity. Finally, the last questions included recommendations and suggestions to improve the educational game.

- ***Results and discussion:***

According to children with dyslexia responses, 100% found FunLexia enjoyable and Fun, and they do not feel bored while playing the game. In the same context, speech therapists say the educational game is a supportive tool, it helps children to learn to read Arabic. Further, the use of different multimedia contents promotes the retention of information. 70% liked the use of multimedia contents such as pictures, animation, sounds, text, and colorful graphics, 30% the monkey character Lexia. Besides, speech therapists highlight the importance of the variety of activities in the game to support Arabic skills such as s recognizing letters, structure of words, identifying letters and words to enhance short-term memory. The puzzle activity 2 is the most preferred activity by children. And the activity 3 is the difficult activity. Hence, the speech therapists say that despite the difficulty of the activity 3, it's important to increase short term memory and concentration. Participants suggest some recommendations and ideas to improve the educational game functionalities. 70% of children need more pictures and songs. 20% of them want a version of 'FunLexia' in French. On the other hand, speech therapists suggest adding more activities to support children on other areas such as phonetic confusion and other activities with missing letters in different position to construct words.

The results from the interview show that children with dyslexia, find the game fun and interesting. And they would like to play the game in the future. Also, the feedbacks obtained from speech therapists indicate that the game can promote the learning process and help to learn effectively.

V. CONCLUSION AND LIMITATION:

This paper presents the design and evaluation of FunLexia, an educational game developed for children with learning disabilities to help them to learn to read Arabic. As mentioned previously, we performed an evaluation which combined heuristic evaluation, experimental methods, and an interview. The purpose of this combined approach was not only to identify more usability problems but also to compare the results obtained from different methods.

The results from the heuristic evaluation and the experimental methods show that the most usability problems found are, the game does not permit target user the move freely and control their action in the game. Further, an appropriate feedback with a clear message, to inform children about the interface they are currently on, and also the next

action is needed. Besides, the outcome of the thinking aloud protocol and interview indicate that children have a good opinion about the use of FunLexia in learning. Moreover, the results from the interview have shown that children find the game enjoyable and exciting. And speech therapists also indicate that the game can promote the learning process and help to learn effectively. Furthermore, they proposed some suggestions and recommendations to improve the game functionalities.

This study has a number of limitations that need to be taken into account. Firstly, the evaluation should be made with a larger number of participants in order to attain more reliable conclusions. Another limitation is that the game does not include the social features. Further work is required for the next version of Fun Lexia, to enhance its usability, as well as suggestions by children and speech therapists. After the validation of the tool, it will be offered to the community freely.

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ANNEX A: NIELSEN'S HEURISTIC EVALUATION

Abbreviations	Usability heuristics	Description
UH1	Visibility of system status	The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.
UH2	Match between system and real world	The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.
UH3	User control and freedom	Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.
UH4	Consistency and standards	Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.
UH5	Error prevention	Even better than good error messages are a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.
UH6	Recognition rather than recall	Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.
UH7	Flexibility and efficiency of use	Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.
UH8	Aesthetic and minimalist design	Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.
UH9	Help users recognize, diagnose and recover from errors	Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.
UH10	Help and documentation	Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.