EasyLexia 2.0: Redesigning our mobile application for children with learning difficulties

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Abstract. Dyslexia is one of the most common learning difficulties affecting approximately 15 to 20 per cent of the world's population. A large amount of research is currently being conducted in exploring the potential benefits of using Information & Communication Technologies as a learning platform for individuals and especially children with such difficulties. We focused on developing an application, which could improve children's fundamental skills, such as reading comprehension, orthographic coding, short-term memory and mathematical problem solving through game playing. In search of stimulating and interactive learning experiences, we first designed and developed a mobile phone application for children with dyslexia. The main core of our research was to assess the usability of the technology and evaluate its effects. We have presented initial research results regarding EasyLexia, a mobile application for children with learning difficulties. In the meantime, tablets and touch screen portable devices were rising in popularity amongst students, leading us on to question whether bigger screens and more processing powered devices could enhance interactivity, usability and overall engagement. In this paper we improve upon our previous research, and present design choices and implementation details of a tablet based game for children with learning difficulties, whilst comparing our evaluation results to our previous research conclusions.

Keywords: Dyslexia, learning difficulties, reading comprehension, mobile learning, software for education, portable tablet PC

Introduction

Problem description & related work

Recent research estimates that a staggering 15% of the world's population may have dyslexia (Society for Neuroscience, 2004). It is one of the most common learning difficulties and a person struggling with dyslexia might show trouble reading and writing in spite of adequate intelligence, exposure and cultural opportunity (Gaggi et al., 2014). Although the disorder varies from one individual to another, some common characteristics among people with dyslexia are, difficulties with phonological processing (the manipulation of sounds), spelling, and/or rapid visual-verbal responding (Rauterberg et al., 2003). Dyslexia could be a life-long condition and its symptoms can vary depending on the severity of their case, but timely and appropriate intervention can deliver significant improvement. Many intervention methods are currently in use, and additional studies are necessary to better understand which techniques offer the best results. Research is now focusing amongst others, on the potential benefits of employing Information and Communication Technology (ICT) to develop interactive experiences and optimistic learning surroundings that could motivate and help children, whilst assisting them to address their disability prematurely and possibly mitigate its various negative effects. Digital technologies can be used in order to train, assist and facilitate the learning process.

Accrediting bodies in teacher education (NCATE, 2008), as well as researchers and educators in the field of early childhood education (NAEYC, 2012), highlight the importance of children's active use of technology in making decisions, technology resources in writing and drawing, and logical thinking programs to solve problems and illustrate ideas (Couse & Chen, 2010). As a result of rapid technological progress, the educational learning processes of the 21st century have been altered and amongst others, it results in the use of new innovative learning devices such as tablets. Peter Mulligan, a Disability Advisor at Sunderland College, advises learners with dyslexia to use their digital portable devices, in order to make learning an easier and more pleasant process (Mulligan, 2011). In fact, by connecting their emergent ideas to prior knowledge and on-going observations, children are starting to understand and view the world in a different light. This development in educational technology can represent the major shift in which a child's mind could be cultivated.

Specifically designed applications can stimulate students' interest, but may also help students with disabilities adjust and progress within a mainstream school environment (Scarlatos, 2006). Thomas regarded ICT as an enabler that can increase student's motivation, foster self-competition, and enhance their confidence and self-esteem (Rello & Baeza-Yates, 2013). Various implementations of ICT in education and learning have been researched, such as the use of websites as educational motivators for adults with learning disabilities (Johnson & Hegarty, 2003), virtual environments (Brooks et al., 1988; Rose, Brooks & Attree, 2002) and computer games (Kazakou et al., 2011; Larcher, 2000) implementations of portable writing aids and configurable word processing environments to support people with writing difficulties (Nisbet & Poon, 1998; Nisbet et al., 1999). People with special educational needs, such as dyslexia, could potentially gain many benefits from ICT (Williams et al., 2006; Dickinson et al., 2002). Keates (2002) explained the need of pupils with dyslexia to access ICT for learning and being introduced to the appropriate ICT, including hardware and software (such as different word processors). The use of multimedia is also believed to assist learners with dyslexia (Rahman et al., 2012). These applications do not only allow, but also reinforce the bimodal presentation of information via visual and auditory channels; thus, information processing is accelerated and mnemonic recall is facilitated (Kazakou et al., 2011).

Tablets and large portable devices create a unique learning experience and can potentially facilitate an enhancement of learning techniques. While mobile and tablet devices differ in design and functionality, both create potential for academic and social progress for children with learning difficulties. The trend of multiple learning techniques, with the help of different devices, brings about a multi-faceted learning process, which is far more engaging for young learners. Mobile learning has become an emerging field while mobile phones have long been researched as an ideal medium. Mobile learning has shown to increase the engagement of younger students during the learning process, but less attention has been paid to the growing number of tablet devices and their use in the educational field. Tablet and similar devices combine the portability and interaction methods of mobile phones, with large processing power, bigger screens and better graphics. It was reported that 75% of students at Oklahoma State University believed that tablets improved their learning skills (BizEd, 2011) and the bigger the screen size, the larger the capacity of the communication channel between the human and the device (Budiu, 2014a). Even though the numbers of children who own their own tablet are lower than those who own a smartphone (51% and 20%), the ones who use tablets on a daily basis are 30% compared to 45% of the mobile phone users, which is not a significant difference (Livingstone et al., 2014). The percentage of 81% of US teachers think that tablets can help enrich learning while improving the understanding of material, digital literacy, creativity, independent thinking and motivation.

In fact, 86% of students think that tablets can help them study more efficiently (Tabtimes, 2014). Tablets might lack true "multitasking" capabilities, but by not allowing multiple applications to be viewed simultaneously, could actually help students focus more on a given task. Also, their nature contrasts with the much more personal nature of mobile phones, which are typically owned and used by single individuals (Budiu, 2014b).

Learning from tablet devices provides an educational experience, which is altering the nature of knowledge (formal and informal) and focuses on the user's experience of learning through the use of digital devices. It provides a wide range of educational and learning material in a uniquely engaging manner (touch-screens), while offering the option to choose from information, which enriches their knowledge and improves their skills. Goral (2011) summarized the main advantages of using tablet technology for the learning process and how it is proven to significantly enhance creativity, digital skills and critical thinking, by the use of reading texts which lead to greater interaction among students and faculty. It is important to state that using tablets for educational purposes is not just about choosing the appropriate device, or downloading specific applications, but how educators create greater potential through these devices and finally revolutionize learning.

Research questions

In our initial research, we focused on exploring the benefits of a mobile application and its potential to improve children's fundamental skills while offering an interactive learning experience, since people are immersed into the digital world more than ever. We discuss our initial research results in our previous paper (Skiada et al., 2014). Through our original interaction with the students, we were able to identify that students were accustomed to tablet devices since they often used their families' devices for playing games. This led us to wondering if such devices, with larger screens and additional processing power, could actually benefit children's learning needs.

We set a goal to research the degree to which such a device could benefit students with learning difficulties. Our research questions evolve around our main scope, which is to improve children's learning skills by designing a tablet application, which could potentially decrease their learning difficulties. With our goal in consideration, we focused on assessing the usability of the innovative technology and how it affects the learning process. The main research question (Q1) remained the same and questions whether digital devices can offer an improved learning experience for children with learning difficulties.

The second question (Q2) posed whether a tablet application in comparison to a mobile application, designed specifically for children, could foster learning on a greater scale and help children with their learning difficulties by improving some of their fundamental skills, such as language and mathematical abilities. Additionally, we assessed whether a tablet application, rather than a mobile application, could improve the learning process by engaging children's attention through a more interactive and immersive experience (Q3).

Finally, from a software engineering and design point of view, we examined the features and design elements, which are required, and questioned the best possible way in which they could be utilized in an application such as this; we sought to examine if these features provide a more immersive and enhanced learning experience for young learners (Q4). All of the above factors are principally measured as the "usability of the application". In the following sections we present the methodology, environment setup, design choices and results of our preliminary evaluation and assessment research.

Methodology

Methodology, school and pilot setup

From the beginning, it was obvious that for the design of this application, we needed a considerable input from students and experts of the field. To achieve this, we employed an agile methodology, which encourages an iterative approach and offers immediate response to changes. Differentiating from the traditional software development methodologies, a combination of Agile and Extreme software development methods stresses the importance of iterative and incremental development, where requirements and solutions evolve through the software development lifecycle. Based on recurring analysis, design and evaluation cycles, rather than a linear design processes, we gathered the outcomes of the final evaluation (Yee, 2002) and we were able to improve various elements of the application during its stages of development.

The design and development occurred in collaboration with the students and the teaching staff of the "Speech Therapy Center", which is located in Syros Greece. We employed a combination of laboratory (emulators) and field study experiments (actual devices) to best evaluate the application. We used a mixed method of quantitative and qualitative analyses in order to reveal statistically significant information related to learning results, gains and insights through the procedure. Current research supports that through a mixed method approach, an evaluator can employ triangulation by collecting both quantitative and qualitative data at different stages of inquiry, which in return can yield more decisive findings (Bebell, Russell & O'Dwyer, 2004; Creswell & Clark, 2006; Frechtling, Sharp & Sharp, 1997; Rello, Bayarri & Gorriz, 2012).

Five students with dyslexia participated in this evaluation study, in two successive evaluation rounds. This number of students conforms to the number of test users required in an ordinary usability test (in an iterative development process the literature proposes 5 to 10 users per test round (Kaikkonen et al., 2005). We categorized the students, based on their level of dyslexia symptoms, gender, age and the treatment period which they have been visiting a therapist. All of the children have been visiting a specialized speech therapist and underwent treatment over a period of 12-18 months. The dyslexia categorization was based on an expert's diagnosis of the students and on a psycho-educational assessment. None of them faced vision or hearing problems and were not native English speakers, but could speak English fluently and spell decently, given their young age. All of the students had learning disabilities and more specifically, phonological - acoustic and superficial – visual dyslexia. The criteria used for the evaluation of each individual were based on the users' age and level of learning disability. In an attempt to develop conceptualizations and evaluation methods for our mobile learning application, we started to consider a more personal and contextual learning process. We focused on the importance of individualizing the application to each student's learning level, by recognizing his or her spectrum of diversity and personal learning needs. It was also necessary to identify whether a minimum level of knowledge was required of the users, during their first contact with the application, in order for one to gain and learn from the application itself.

The students, which were involved in the evaluation process, were ages 7 to 12. This first evaluation sample, offers information involving time, levels and clarifications needed from each child. The average time for users to complete a level was measured from the minimum of 1:00 minute until the maximum of 2:00 minutes. In each game, the number of errors was measured on a scale of 0 to 4. Also, a larger number of users required clarifications and game instructions in comparison to those who found it easy to proceed without any additional guidance. We also set up a "control group" by recruiting 5 students of the same

age group who had not been reported or assessed as having learning difficulties, so as to ground the results of the previous data, we uncovered potential issues.

The comparative use of the application and the subsequent data analysis also allowed us to determine whether the outcome of our evaluation was actually related to learning difficulties or other factors (design choices, technology, computer experience etc.). For instance, the knowledge of the English language was set as an important precondition for the users of this application. We chose to develop the application in English, in order to reach out to a larger market, even though we observed that some non-dyslexic children encountered difficulties completing certain levels due to their knowledge of the English language, rather than their inability to learn. Lastly, we surveyed the children's parents in order to record their point of view and their concerns. This information helped us achieve a better understanding of the environment in which children with dyslexia function and of the difficulties they encounter everyday (the presentation of these results was here omitted due to space restrictions). The characteristics of the users, such as their emotions, values and prior experience, determine how users perceive a game and the related learning goals. In general, user experience should be considered exhaustively from physical, sensual, cognitive, emotional, and aesthetic perspectives (Kiili et al., 2014). Thus, we argue that plain ease of use does not guarantee good user experience and engagement and it is our goal to ensure that users find value in the application we designed. We attempted to assess this from follow up interviews and consecutive evaluation tests in the near future.

Design Choices

EasyLexia 1.0 design & features

The original mobile phone application was structured around three basic categories and each category was comprised of three different games. The benefits of game playing as a learning process (in a pedagogical perspective) has been widely acknowledged (Bruer, 1994; Gee, 2007; Papert, 1988; Prensky, 2003). The first category "WORDS", aimed at exercising and improving the students reading and writing skills through an educational and entertaining process. In the first game "Word-finder" (Figure 1), children were asked to identify the correct letters, which addressed the gaps, in order to find the right word. The second game "Choose it", focused on the child's ability to first listen and thereafter recognize the word (which was spelled correctly) from the five given ones. Except of phonological processing, researchers have discovered that children with dyslexia also experience a deficit in auditory processing (Kopko, 2008).Thus, we had designed a third game, "Sound-finder" which consist of sentences with missing words, while combining phonological recordings of the word.

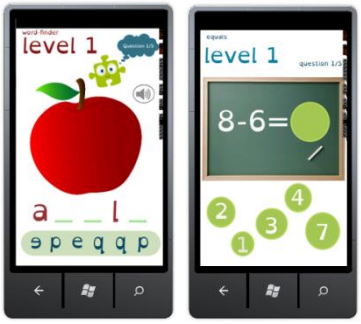

Figure 1. a) "Word Finder" game layout from level one; b) "Numbers" game layout from level one

Research suggests that not all individuals with dyslexia face problems with mathematics but the majority shows signs of struggle. For that reason the second category named "NUMBERS" (Figure 1b), dealt with problem solving since "studies have shown that approximately 60% of dyslexics have a problem with mathematics" (Rahman et al., 2012). The aim of this category is to develop and support children's mathematical skills. Children with Dyslexia often confuse mathematical symbols and find it difficult to identify because they do not recognize the wide range of symbolic representations of math concepts. The two games, which exercised these mathematical skills, were the games "Equals" and "Symbols" respectively. Their main purpose was to help children familiarize with the symbols which were most commonly used in the mathematical field but which would later on express multifaceted mathematical ideas. After conducting research, we specifically selected commonly confused numbers (such as 6 and 9). The third game "Clock", involved a time telling game which is found to be a difficult process for all children.

The third category "MEMORY", contained visual and auditory/verbal features and had a beneficial effect on all types of memory difficulties. The first game "Memo" was an ordinary test working memory game, which purpose was to find the matching pairs of the given cards where the first one spelled out the word and its pair depicted it. This game helped improve their visual memory, because children did not only have to memorize the pictures, but simultaneously analyse the meaning of each word. In the second game "Shapes", the children had to recognize, memorize and identify visual shapes in order to redraw and choose them. The third game "In-order" was a sequential memory game. Random numbers from 1 to 9 moved across the mobile's screen in a random sequence and children were asked to re-write the numbers in the correct order.

Finally, there was a narrative storytelling feature, "BOOKS", which aimed to strengthen children's concentration through reading. With this feature children increased their interest in dyslexia friendly books, broadening their vocabulary and spelling, whilst enhancing their imagination. The selection of books was made based on the guidelines of Dyslexia Action research (Economides, 2006). First of all, the books we chose consisted of stories that were age appropriate for our target-group (7-12 years old). Also, the explanatory pictures helped users follow the stories with ease and enjoyment, while the sentences and paragraphs of each book were short and easy to read. The layout of the selected books was specifically designed for children with reading difficulties. Finally, these books were well structured, offering simplicity in information and the syntax of words. It is very important for the parents to participate in this process and encourage their children to join in by discussing the book's content with them, including picture descriptions and what may be happening" (Economides, 2006). They can also help their children by bonding with them in the reading experience and word finding process.

Moreover, our application introduced a special email operation, which enabled the parents to receive day-to-day information involving their children's progress and score achievements. Finally, the child was given the option of a "like" button, which automatically sent a notifying email to his or her parent; noting that their child favored the specific book. The parents could find additional information of the books by selecting a link of an online bookstore.

The application was developed on windows phone 7 & 8 platforms, in accordance with the industry standards and guidelines.

Evaluation of EasyLexia 1.0

For evaluation purposes, we observed students interacting with our application in a classroom, under the supervision of their teacher, while we obtained qualitative and quantitative feedback. One of our main objectives was to identify design issues and possible breakthroughs (indicating productive new forms of learning or important conceptual changes) or breakdowns (where a learner is confused with the technology, is asking for assistance, or appears to be struggling under a clear misunderstanding) (Vavoula, Pachler & Kukulska-Hulme, 2009).

We evaluated the usability of the application within the learning environment by employing the well-researched generic usability attributes (Danesh et al., 2001; Frøkjær, Hertzum & Hornbæk, 2000; Nielsen, 1993; Paternò, 2002; Zhang & Adipat, 2009): learnability, efficiency, memorability, user satisfaction, effectiveness, simplicity, performance and comprehensibility. During the evaluation, we measured how easily students completed specific tasks, how fast their performance was and how many errors they made during the process. The readability, their understanding of the content and their ability to remember info and features of the application (the ability of something to be easily remembered by someone) are some of the significant evaluation outcomes, which helped modify our application. All of the above data was collected through interviews and on location usage of the application.

While conducting the evaluation, a question arose whether the children should be guided through each game of the application, or left without guidance. The prior option offered more secure outcomes whereas the latter could possibly help reveal problems and difficulties, which could potentially improve the user's interaction.

Guidance by teachers and facilitators are key components for the children and the structure of their activities (Tidwell, 2005). Therefore, we applied two different strategies when handing the application with the users:

With guidance: Children were guided through each level with the help of an instructor, who offered verbal and gestural help. The tasks appeared to be easier for the children, since their questions were immediately solved, just by a pointing instruction.

Without guidance: The children were given the application and asked to begin playing without any further instructions. "Without the constant guidance of a teacher, students […] easily become distracted, confused or frustrated (Paternò, 2002).

Taken together, the two strategies showed different outcomes. We took into consideration the second strategy that indicated important results regarding the application's usability and addressing user interface and interaction design requirements for young mobile learners.

The basic problem that was noted was the difficulty of children trying to type specific letters on the keyboard, while in some cases they found it difficult to use complicated English vocabulary. Those were both very important factors for evaluating our application, since typing and the use of English were both inevitable features of our application. We noticed that the game consisted of many procedural steps until the user began to actually play the chosen a game. Therefore, the usage time was lengthened and an increased sense of insecurity and confusion was noticed when the time was limited. Following the feedback received by the students, we redesigned a number of aspects of our application, including:

- **Choice of Font:** "The presentation of text has an effect on the reading performance of people with dyslexia" (Rello & Baeza-Yates, 2013). After extensive research, re-evaluations, we studied the impact that font styles have on readability, we extracted

data, which proved that sans serif fonts, such as Arial, Helvetica or Verdana or the mono spaced font Courier font types preceded to better readability. (Rello et al., 2012). Furthermore, specific font types such as these can significantly decrease the users reading time and increase their performance (Society for Neuroscience, 2004). The change of font aimed to formulate an easier and clearer interface, increasing the user's readability skills.

- **Text Layout:** The use of certain text conditions can help people with dyslexia read the text with greater ease (Rello et al., 2013a). Therefore, font size for readers with dyslexia should begin at 18 to 26 points and the recommended colour is black, its RGB is#000000. It is possible that larger print size facilitates dyslexic reading by increasing the visibility of spatial frequencies critical for letter recognition or reading (Bruer, 1994; Frechtling et al., 1997; Van Daal & Reitsma, 2000). Also, we positioned the text based on left-orientation for readability matters. Finally, we did not alternate different typographical cases according to difficulty (Prensky, 2003).
- **Background colour:** A white background appeared plain and not invigorating to the young users. After conducting research, white backgrounds were not preferred due to the high contrast, which it produces. Colours such as cream and pastel are ideal for children with dyslexia and often users even prefer to choose their own background colour. The RGB for the cream colour is #FAFAC8 (cream) and with a colour difference of 700 and a brightness difference of 244" (Rello & Baeza-Yates, 2013; Rello et al., 2012). The use of cream backgrounds allegedly softens the glare and improves legibility.
- **Buttons and abbreviations:** We carried out research and retrieved information based on the user interface and user experience of the application. The elements that were implemented were basic functional buttons and controls (start, stop, etc.), which were all redesigned. Therefore, users were given the opportunity to get acquainted to the interface of a mobile phone and adsorb its basic control buttons.
- **Customization:** Having known that emotions are documented on having great influence on learning, we focused on personalizing the application. By personalized learning, we mean recognizing diversity, individuality and differences in the way learning is developed, delivered and supported (Zhang & Adipat, 2009). Hence, at the completion of a level, the personal username appeared on the screen to congratulate the user, triggering positive emotions and feedback, acting and expressing positive emotions to the examinee trying to develop, maintain and increase his positive emotions (Rose et al., 2002).

EasyLexia 2.0 design and features

Porting an application from a mobile to a tablet is a complex process requiring the complete redesign of many features. Unfortunately, it is not as simple as enlarging buttons and fonts, since these devices offer a complete new array of features and a whole different experience.

To successfully port this application into a new device, it was crucial to take into consideration the principles and guidelines of the user's interaction experience and the information design in order to augment our applications' usability and value.

Basic visual design components were re-designed and prioritized. The core features, which were more relevant, were presented and used in a new context and environment, while ensuring that the basic features were optimized for a tablet device. The interface elements

were carefully examined and eventually chosen and input controls, navigational and informational components were important to be reconsidered in this new context of use.

The main focus was to utilize the larger screen of the tablet device, placing interaction mechanisms in new positions and having to design at large. The grouping of information, keyboard and touch interfaces became important factors for an optimal transferring of our application onto a different type of device other than a portable mobile phone.

On mobile devices, various approaches are used to overcome the devices restrictions, such as its small display screen that reduces the user's input capabilities. But with design guidelines, the applications' structure and navigation can help customize the specific design, by effectively altering the applications appearance and actions. By conducting further research on control design, innovative ideas arise from recent results which show that if sound was added to buttons, then they could be reduced in size from 16×16 to 8×8 pixels without much loss in quantitative performance (Brewster, 2002). Also, the keyboard can also limit the user's input actions by hiding a large portion of the device's screen or triggering multiple errors during the typing process.

These factors are not an issue on most tablet pcs, where the screen is larger and the functionality of the keyboard and controls are enhanced. Tablets and touch screen portable pcs could offer additional benefits, for instance the added processing power could support a larger array of animations, improving the interactivity of the game. This could benefit the overall engagement of students and create a visual advantage, which could impact users' skills.

A larger screen could support specialized solutions and upgrade the application's user interface and interaction controls, in order to serve its user's needs. Possible solutions could involve introducing larger fonts, buttons, controls and additional design assets, all of which could assist and provide solutions to many problems. The points presented above, initiated our interest in a different platform, which could potentially offer solutions to a mobile device's restrictions. Therefore, we decided to port our games on to windows based tablets and evaluate the potential benefits.

Design Choices

We redesigned an application as a level based score game that implements a number of puzzles and tests. We began modifying the previous version of the application by re-designing it's "Main page" (Figure 2a) since research has shown that visual thinking skills mainly depend on pictures, shapes and animations, in order to stimulate the eye sensors with the brain processes and enhance imagination and picture creation. We made full use of available animations and storyboards while avoiding any additional user interface complexity. Our goal was to keep the interface clear, consistent, readable and easy to use. The main modifications apart from the font and layout were focused on the user experience and game play, as all tablets have solid reading features for individuals with dyslexia. In particular, after noticing a variation of time depending on the user's age and game difficulty, we altered the number of levels and questions in each game. As a result, we increased the questions from five to ten, in comparison to the previous version. Therefore, the application can more accurately count the user's time and score ratings, whilst precisely measuring his or her performance. On the other hand, the levels of difficulty were decreased from four to three, "Easy", "Medium" and "Hard" (Figure 2b). This change led to a better-balanced system, which can optimize the user's experience, whilst maintaining a selection of challenges and making the game more stimulating. The level of difficulty increases in the range of the ten questions in each stage, have variable content, but all measure the same variable.

Figure 2. a) Main page layout; b) Levels page layout

Since dyslexia is a neurological learning disability that affects reading and writing, words that are new, rare, very long, complex and phonetically and orthographically similar (Rello, Bayarri & Gòrriz, 2013) we proceeded very carefully in reselecting the words used in each game.

In the first category, "WORDS", we recreated three games to address each of the three dimensions of the language difficulties which people with dyslexia experience, difficulty with orthography, phonology and vocabulary. Many researchers believe that developmental dyslexia is characterized by difficulties in phonological processing, specifically phonological awareness, which is the ability to identify and manipulate the sound structure of words. Based on the aforementioned research, phonological awareness and processing is believed to ameliorate with targeted practice. By processing and comprehending the students difficulties and decreased ability to recognize and identify certain words and sounds, we redesigned the first game, "Word-it ", which is aimed to address the difficulty in orthography and phonology, while its three different levels concern the orthographic similarity of words, letter recognition and recollection. Therefore, the children are asked to retrieve information from their visual cortex, where the images are being analysed and compare them to the language processors of the brain. It has been observed that children with dyslexia find it especially confusing to tell time with an analogic clock. Moreover, we observed that they may be able to tell whole hours and half hours (4:00, 2:30 etc.) but details such as the exact seconds (6:08) are often eluded. Furthermore, "they find it difficult to distinguish between the minute and hour hand" and finally signal words, such as before (to) and after (past) can be easily confused. Thus, we chose to create and design a new game, which aims to improve both orthographic and phonological skills.

The second game "Choose-it" (Figure 3a) was also focused on phonology, phonetically similar words, irregular and homophonic or pseudo homophonic words, but in a different layout (Rello, 2014). This game, requires from the children to choose the image which best describes a given word. In addition to the above alternations, we integrated phonetic pronunciations after the completion of each word or phrase.

Figure 3. a) "Choose-it" game layout, level one; b) "Equate-it" game layout, level one

It is noticed that in order to "aid memorizing the teaching, it has to be multisensory, which means that it is important to involve as many senses as possible. Thus the pupil is encouraged to look carefully at what he has written and to listen carefully to the sound of the word" (Brooks et al., 1988).

The application has been developed based on the understanding of dyslexia's nature and how it affects learning. It not only focuses on the writing and reading process, but also on mathematics and problem solving. Hence, in the second category "NUMBERS", the most important alteration was made in the game "Symbols", which was renamed as "Sequence-it" (Figure 3b). The content of the game was altered and now the purpose of the specific game is for the user to place the given numbers in an ascending order, from the lesser to the greater. The game's main role remains the same, which is to enhance the comprehension of symbols and their use. The changes which were made were mainly in the layout, which is totally different from the original and is much more interactive and immersive. The design offers a powerful interaction pattern, which is enhanced through the use of a tablet device.

In the third category "MEMORY", we changed two out of the three games. The second game "Puzzle it", is a creative game in which the child must complete the missing pieces to finish the puzzle. This game has been replaced from the game "Shape-it", where in the second and third level, pictures of shapes are shown and the given task is to draw the depicted shape. The third game "Recall it", is a memory game that requires the player's concentration and focus, since he or she must recall the numbers, letters or images that appeared on the screen. The levels of difficulty are proportionally altered based on the number of symbols, which the user is called upon to remember.

We formulated all these game changes with the core motive of creating a more whole and accessible application by collecting all of the components we used in our mobile app and reorganize them in a better and more suitable structure.

The changes in the "BOOKS" category in the tablet application were aimed at offering increased opportunities for discovering new ways of reading and interacting with information, complemented by audio and images which can be read as well as watched. Reading is considered by many researchers to be the most complex function, requiring a high brain performance. When you read, your brain has to search through your mental dictionary and has to connect them with their meanings in order to make sense within the context of a complete sentence or thought. You are actually converting characters into word sounds and then combining those words into speech. For individuals with dyslexia, the words are not mentally sounded out in the same way as they are read. In fact, despite of the current popularity of phonic methods for teaching students how to read, dyslexics usually do better at sight-reading, where they simply recognize an individual word as a concept (Davis & Braun, 2010). For this reason, new audio features were added, creating a wider range of personalization for each individual's needs, such as the choice of listening to different kind of audio recordings. They can choose a male, female or a child's voice, whichever is more familiar and/or more pleasant to them. This might be expected to contribute to an increase of concentration and attention, as recent research has shown that students who were given the chance to listen to the text, change the font size and take notes, achieved a better understanding of the book's contents (Pledger, 2010).

Lastly, the scoring system employs a calculating feature, which counts up to 10, similar to the respective number of stages. But scoring grades such as A, B or C, are presented to the children, in order to boost their confidence. The parents and teachers receive their children's score in decimal points, offering them a more detailed evaluation. The evaluation process has gained a playful "mascot" which appears whenever an answer is given, either

encouraging the children in case of a possible error or congratulating them in the case of a correct answer.

Evaluation of EasyLexia 2.0

Methodology

As previously, we piloted our evaluation process at a "Speech Therapy Center", located in Syros Greece. The usability method tools were carefully chosen and were based on identifying the test metrics, which were best for the specific evaluation process. However, we used one of the ten categories used in evaluation studies, according to Tullis & Albert (2008). The scope of our usability testing iteration was to examine the use of a mobile phone device in comparison to a tablet device. The first evaluation measurement that was examined was "the successful task completion". Task access and the ease of use, could be assessed in a great variety of processes and can extensively measure qualitatively and quantitatively the degree of the user's ability to complete each task. Another evaluation measurement that was used was a "time on task" metric, which is a measurement of the degree of efficiency in performing an operation in both digital mobile and tablet devices, proportional to time, as well as if there was an increase in the child's engagement. The last evaluation measurement, which was used, was the number of the user's errors during their playtime in two different games, categories and devices. We didn't measure the learnability due to the sensitive memory skills of our users. Throughout interaction, the mistakes that were made, were clear, as well as the recording of the frequency of mistakes, both of which are important usability measurements (Koutsabasis, 2011).

The same five students with dyslexia participated in this evaluation study, in two successive evaluation rounds. The purpose of the iteration was to provide us with an indication of what could be the advantages, which could arise by the use of tablets compared to mobile devices, but not providing significant statistical results. All of the users of the evaluation process had daily contact with such devices and had at least one of the digital devices in their household.

Observations from the quantitative metrics

We categorized the sample of students based on their gender, the level of severity of dyslexia symptoms, age (categorized into two different age groups, 7-9 and 10-12) and the period which they have been undergoing treatment, since their first visit to the speech and language therapist (Table1). All of the children have been visiting a specialized speech therapist and underwent treatment over a period of one year.

This usability test could also be referred to as a "first click" testing. Research suggests, that a tester who clicks down the right path on the first click, will complete their task successfully 87% of the time, whereas someone who clicks the wrong options, will successfully complete their task only 46% of the time.

While examining the children's interaction with the tablet, we tested the success of the task completion with the use of a pen tool and the use of their fingertips. While the pen interaction can serve as a precise pointing tool since fingertip movements are always more imprecise and the chances of unintended errors are increased, it often distracted them from their given task and spent 20-25 seconds more than touch interaction.

In fact after each task, the children were asked to describe their experience, how easy they found the given questions, if they enjoyed it and if they found it intriguing. All of the children's responses involving the tablet were positive and showed great interest and persistence while using it, without a sign of frustration.

Table 1. Students involved in the evaluation process

	1st User	2nd User	3rd User	4th User	5th User
Age (years old)	12	10	11	12	8
Gender	Boy	Boy	Boy	Boy	Girl
Dyslexia Categorization (the level of severity of the user's difficulties)	Mild	Moderate to Severe	Mild to Moderate	Severe	Moderate
Period of specialized intervention and treatment	9-11 months ago	9-11 months ago	23-25 months ago	24-26 months ago	12-14 months ago
Time to complete a Words level on a Mobile device	25-30 sec	25-30 sec	1min	35-40 sec	30-35 sec
Errors (made by game)	1	0	2	2	1
Time to complete a Words level on a Tablet device	30-35 sec	20-25 sec	35-35 sec	45-50 sec	20-25 sec
Errors (made by game)	0	0	2	3	0
Time to complete a Numbers level on a Mobile device	50-55 sec	35 sec	25-30 sec	40-45 sec	30-35 sec
Errors (made by game)	1	0	1	2	1
Time to complete a Numbers level on a Tablet device	30 sec	50-55 sec	35-40 sec	25-30 sec	30-35 sec
Errors (made by game)	1	0	1	0	0
Clarifications needed on the mobile device	Yes	No	Yes	Yes	Yes
Clarifications needed on the tablet device	Yes	No	Yes	Yes	No
Found the app more intriguing on a tablet or on a mobile version	Tablet	Tablet	Tablet	Tablet	Tablet

The categorization of the level of severity of dyslexia symptoms was based on an expert's diagnosis of the students, according to a psycho-educational assessment. None of them faced vision or hearing problems and were not native English speakers, but could speak fluent English and spell decently given their young age. All of the students had learning disabilities and more specifically, phonological - acoustic and superficial – visual dyslexia. The criteria used for the evaluation of each individual were based on the users' age and level of learning disability.

Responding to the original research questions

After having conducted the experimental evaluation, we gathered the results and analysed the student's progress while answering research "Question 1". Most of the students indicated a higher performance when using a tablet device in comparison to their mobile score achievements. They didn't need constant reading or writing assistance in either of the

devices and reading and writing became an easier process for most of the participants. The new layout and features of the application were easily understood and students got immediately familiar with the new design elements, while utilizing all of the features without the need of any assistance. During our evaluation process, evaluators asked all of the participant students which version of the application they best preferred. The whole sample answered that the newest tablet version was most satisfying. We also noticed that the larger screen space offered a clearer understanding of the text and children were able to insert their input with greater confidence and precision. New clarifications and instructions helped guide and navigate children with greater ease through the application. Last, the new interactive features which were added, such as images, animations and sounds, gave the children the opportunity to collaborate and immerse into their given tasks, while collaboration was impelled. We encouraged collaboration through our design, since sharing ideas can be stimulating to their imagination, and this seemed to lead to important gains in their ability to interact, share ideas and cooperate with others. By evaluating the application with a group of students, our first significant observation was that all of the students showed preference in practicing and completing the tests on a portable device (mobile or tablet) rather than on paper. An interactive learning application helps children with dyslexia to concentrate and ignore distractions while learning, by targeting their attention on the device's touch screen. The previous result indicates the significance of technology in today's learning methods.

The duration of each test can vary depending on the dyslexia symptoms and severity of each user. Regarding research "Question 2", when comparing data between a tablet and a mobile phone application, it was indicated that the time and number of errors that were made per game had been decreased. Therefore, we could potentially identify over a short period of time, an overall score improvement. This observation agrees with documented research on the issue (Kazakou et al., 2011; Van Daal & Reitsma, 2000; Wise, Ring & Olson, 2000).

Overall, the research questions dealt with the comparison of a mobile and tablet application and researched, which of the two offer greater opportunities and more immersive experiences "Question 3" and "Question 4". However, the need for information and the increasing degree of educational autonomy requires a proactive approach. Hence, curiosity and exploration in the digital world, which are the natural drivers of learning, enable an even faster retrieval of desired information. The integration of mobile and portable technologies into the educational system goes beyond its sole availability (Bedi, 2014).

The use of digital tablets for the learning process is proven to significantly improve the children's understanding of topics, digital skills, creativity, independent learning and motivation. It is important to state that using tablets for educational purposes is not just about choosing the appropriate device, or downloading specific applications, but how the educators create greater potential of these devices and finally revolutionize learning.

An important overall finding of our work was that of the importance of design selections when implementing software interfaces for children of any age group. Certain design selections regarding colours, fonts and etc. can make an application completely inoperable to certain children. Small improvements in such aspects can bring upon large results. The applications that are easy to use are designed to be familiar (Wise et al., 2000) and although we recorded an increase in the game clarifications which children needed, most of the children's reactions towards the application was overall positive. Good software, allows people to put on trial something unfamiliar, without backing out and trying something else, all without stress (Papert, 1988). The design of a dyslexic friendly environment acquires specific principles and could be difficult to follow since the interaction with the system demands to be as immediate as possible. The immediacy of changes on the screen in

response to user actions proved to be one of the most popular aspects of the new system, called direct manipulation (Vavoula et al., 2009). Every design element is crucial, since the use of words and pictures together require a special sensitivity to the purpose of the design (NINDS, 2011). Therefore, the goal of improving the design of text for children with dyslexia is not just helping them with phonemic awareness or fluency but rather accessing the concepts and ideas which the letters and words represent. We need to design effective systems, which will improve learner's skills and increase their productivity (O'Brien et al., 2005).

Conclusion

Given the potential benefits of an application for children with special learning needs, we focused on designing an application that is aimed at improving their skills through the use of advanced and assistive technology. By testing the advantages of a tablet over a mobile phone device, the results are not absolute but are fundamental to an early understanding of what could be done with new technology and how it can affect young learners. To sum up, the advantages of new technology depends on two factors, the way educators implement technology and the individual's persistence and involvement for a more efficient and effective use. In combination of the above, new technological integrations can create new learning processes with great effectiveness and impact on young learners. The application was designed and implemented in a two-phase iterative research and methodology development with the collaboration of students and teaching staff from the "Speech Therapy Center" in Greece. We are certain that ICT can help children with dyslexia and improve their reading and writing abilities. The evaluations indicated an overall progress in the user's game performance, despite the short period of time. Most importantly, from testing the application's effectiveness we observed that tablet applications aimed for children with dyslexia, could potentially be more engaging than mobile devices. It is our intention to further continue our research in this field, by testing the application's effectiveness and value over an extended period of time, to better assess new innovative learning methods and their outcomes reflected on the user's skill improvements.

Acknowledgements

We would like to thank Mrs Moscha Kontorousi (Speech-Language Pathologist) and her Speech-Language Center for Children & Adults, for her professional guidance during the entire research.

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To cite this article: Skiada, R., Soroniati, E., Gardeli, A., & Zissis, D. (2014). EasyLexia 2.0: Redesigning our mobile application for children with learning difficulties. *Themes in Science and Technology Education*, 7(2), 119-135.

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