

Mobile Applications, An Emerging Powerful Tool for Dyslexia Screening and Intervention

A Systematic Literature Review

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Abstract—Nowadays, mobile smart applications seem to play a vital role in dyslexia screening and intervention, accumulating numerous assets and comforts in according to dyslexics students' needs and their learning pace. Initial detection of students' disabilities, followed by a corresponding intervention program are the best combination of actions in an attempt to any problem be confronted effectively. In our today's society, mobile smart apps have been considered as an alternative approach for the success of these key steps, as well. During the last decades they have been developed or have been implemented, focused on different aspects of dyslexia symptoms (reading, writing, mathematical difficulties, memory etc.) The aim of this systematic literature review was to report a great number of mobile smart applications for dyslexia screening and intervention. The final 26 studies were selected, which have been conducted from 2012 to 2019. These papers were categorized into two sections. The criterion was the purpose of their use at a time. As a result, the first classification reflected a mobile app as a detection tool, while the second one presented the mobile app as intervention tool. Research revealed that a greater number of mobile applications were designed to intervene in dyslexic symptoms, compared to applications for detecting this disorder. A significant percentage of mobile smart apps for dyslexia screening assessed a range of symptoms. However, mobile smart apps for dyslexia intervention assisted students with dyslexia to develop mainly reading and secondarily other skills.

Keywords—Mobile applications, Dyslexia, screening, intervention

1 Introduction

Mobile smart phones are becoming an emerging power in learning as an integral part in daily culture for teachers and students. They remove temporal and spatial complexities, introducing new forms of communication [1]. A variety of touch devices such as

iPods, smartphones, e-toys, smart boards, tablets and more to play are gaining popularity among young users, who learn and communicate in new manners and spend various amount of time in front of screens through this condition [2] Research has come to light that young children are so engaged with the mobile apps and are keen on playing with them a great deal of time depending on the structure and content of the app and their interests and needs [2]. Parents are also supportive, as the majority of them maintain positive attitudes towards the use of these technologies according to a Greek study, involving 293 families [3]. Encouraging results have been reported by parents and teachers for the use of mobile apps and devices and also professionals have indicated that these tools could be a versatile instrument for students with learning disabilities [4].

In contemporary times, mobile smart devices are considered to be a distinctive prospect of learning process. The use of mobile-learning in education encourages students to build and gain their own thorough knowledge in content through innovative learning spaces. They enhance students' academic performance, developing the procedure in a novel and dynamic manner. This strategy promotes individualized learning and pupils' autonomy according to their needs and requirements thanks to the portability and accessibility of them. Mobile phones are a cost-effective educational method, constituting a lighter mode in comparison with laptops and books [5], [6].

A significant proportion of mobile apps have been designed for dyslexia screening and intervention. Dyslexic students generally exhibit different characteristics such as spelling problems, slow laborious reading, disabilities related to word reading and phonological awareness problems [7]. Mobile apps might also be known as apps, smartphones apps or iPhone apps and work with formulas, software and screens, including e-books, mobile learning, comics and graphic novels [2] [8]. Numerous mobile devices (e.g. self-phones) have been developed with the view to assisting the screening of dyslexia signs or supporting their reinforcement of dyslexics' specific learning skills, such as writing, reading (e.g. note taking, composing text etc.), spelling, memory, metacognition etc. [9], [10], [11], [12]. Also, the mobile technology ought to be incorporated into curriculum. The curriculum should be focused on developing methods for supporting dyslexics and identifying the flaws of it, that inhibits teaching students with dyslexia. Dyslexic students' problems can be diminished through individualization of learning instruments and universal design for learning, which can be promoted by multimedia [9]. The research findings revealed the effectiveness of multimedia technologies, referring to a range of mobile smart apps (mobile devices, graphic novels and comics, e-books), which were recommended for multisensory education for language disabilities [8]. Research reported, also, a proposed evaluation rubric describing characteristics of instructional apps for students with learning disabilities. This model was focused on three main sections [4]. These are presented in the following table. (Table 1).

Table 1. A proposed evaluation rubric describing characteristics of instructional apps for students with learning disabilities [4].

Section	Characteristics
First section: “Identifying Information”	1) Instructions for primary and secondary areas, 2) Basic information of an application, 3) Objectives of an application 4) User’s level or age relative to the content (“content level”), 5) Types of an app and 6) Kinds of theme level and graphics (e.g. images, language etc.)
Second section: “Evaluation”	1) Strategies that use an app to encourage students, 2) The quality of objectives, 3) Actions relative to students’ practice, 4) Examples in the app for effective learning, 5) Analysis for the types of error that students make, 6) Error correction and feedback for their performance, 7) Progress monitoring, 8) Accessibility and navigation, 9) Students’ motivation and engagement, 10) The design of the font, 11) Auditory and visual stimuli, 12) Customized and individualized settings and 13) Errors and bias associated with the content.
Third section: “Grading”	The total score percentage of the scores for each section and the number of categories through an assessment procedure of the app

In this article, a systematic literature review of studies about mobile smart apps for dyslexia is presented. These papers were classified into two main categories related to the role of the tools in the manipulation of dyslexia symptoms. In other words, mobile smart apps for dyslexia detection and intervention were described in two discrete sections. The former was dedicated to the dyslexia detection procedure and the latter was focused on the dyslexia intervention. These apps were also inspected, based on what signs or difficulties of this disorder have been focused.

2 Methodology

In the present study, the data, related to the research topic, were collected through the Systematic Literature Review. The steps to summarize the research evidence were 1) formation of the research questions, 2) decision for selection criteria for the resources, 3) reference to search strategy and search process as a whole, 4) extraction of information from resources and 5) analysis of the data extracted.

2.1 Research questions

The main purpose of this systematic literature review was to report a great number of mobile smart applications for dyslexia screening and intervention. Thus, the following research questions were raised:

1. What mobile smart applications have been designed for dyslexia screening?
2. What mobile smart applications have been designed for dyslexia intervention?
3. In what dyslexia symptoms mobile smart apps have been mainly focused for screening and intervention?

2.2 Selection criteria for the resources

Specific selection criteria were taken into consideration to determine which studies were included in this systematic literature review. Particularly, the criteria were that: 1) articles referred to studies have been carried out from 2012 to 2019, 2) researches were focused on the present research theme and research questions (e.i. mobile smart apps for dyslexia screening and intervention) and were relevant to this mobile computing section, 3) studies were written only in English, and 4) papers described pilot studies or empirical researches or usability, functionality and evaluation tests for the mobile smart apps, as well.

2.3 Research procedure

This research was based on data that were available in “Google Scholar” (<https://scholar.google.com/>), as a main data resource and other digital sources, named “JSTOR” (<https://www.jstor.org/>), “Springer-International Publisher Science , Technology, Medicine” (<https://www.springer.com/gp>), “Science Direct” (<https://www.sciencedirect.com/>), “PubMed” (<https://pubmed.ncbi.nlm.nih.gov/>), “IEEE Xplore” (<https://ieeexplore.ieee.org/Xplore/home.jsp>) and “Online-Journals org” (<https://online-journals.org/>).

Particular keywords, related to targeted search terms were used, in order for us to accumulate the data. The studies were oriented mainly towards the following elements: 1) mobile apps or mobile applications for dyslexia, 2) dyslexia screening or mobile dyslexia screening or mobile applications for dyslexia screening/ dyslexia detection or mobile dyslexia detection or mobile applications for dyslexia detection, 3) dyslexia intervention or mobile dyslexia intervention or mobile applications for dyslexia intervention.

The number of papers, which was obtained from the main digital source without criteria and limits was 14.300 for general terms related to mobile apps for dyslexia and especially 4.050 for mobile applications for dyslexia screening and 8.800 for mobile applications for dyslexia intervention. The number decreased significantly, when the study was limited to the years 2012-2019. Specifically, there were 8.690 papers for general terms related to mobile apps for dyslexia, 2.260 for mobile applications for dyslexia screening and 5.450 for mobile applications for dyslexia intervention. The studies were evaluated considering their language and some papers were discarded in this phase, as well. The texts of the remaining 110 studies were inspected. After this action, the remaining 33 studies were evaluated, as they were relevant to the research purpose. During this phase, 7 papers were excluded too, as they didn’t provide information about pilot studies, empirical researches or usability, functionality and evaluation test for the proposed mobile apps. In this way, 26 papers were the final data, which was analyzed to cover the research content of this literature.

3 Results

3.1 What mobile smart applications have been designed for dyslexia screening?

First classification of the literature review was about mobile smart apps for dyslexia detection. Based on the results of the Systematic Literature Review, 12 papers (46,2%) presented studies about mobile smart applications for dyslexia screening. A significant number of them has been developed to facilitate this procedure.

Particularly, in Colombo, Sri Lanka, a new mobile application was produced, called “The CURE”, so as to assist people with dyslexia and dysgraphia. A great number of sequential revised steps were followed to define both the requirements and the accuracy of this tool. Approximately 100 patients with dysgraphia and dyslexia, expert health professionals and specialized doctors took part in this study. Results showed that this application met individuals’ with dyslexia and dysgraphia needs, related to the progress of their reading and writing skills [13].

In Spain, a magnificent puzzle app was introduced, named “DysPuzzle”. The aim was to identify pre-readers with potential dyslexic problems, applying screening criteria, linked to motor skills and characteristics. Thus, in this process a usability test was implemented, inspecting 10 German-speaking children (aged 3-6 years old), accompanied with their 5 parents. Obviously, the majority of kids were amazed and intrigued by this mobile application. They comprehended the navigation and rules of the game easily, since the appropriate guidelines were given. Also, parents interacted with game-puzzle, understanding the data input. This tool was considered to be a novel mode for detecting dyslexia in kindergarten [14].

Moreover, in Bologna, Italy, an android app with the intention of detecting kids was proposed, enrolled in second class of the elementary school with reading disabilities such as dyslexia. In this experiment, some primary students were tested, playing the application twice under supervision. Then, a questionnaire (“Post Experiment Questionnaire”), related to usability, understanding and difficulty of the environment and views about the app, was filled in by 43 participants. Further preliminary study concerning the validity of this instrument took place, involving 9 children. Researchers came to the optimistic conclusion that the tool could screen students with reading difficulties successfully, being an appealing app [15].

In Sao Paulo, Brazil, a mobile application for dyslexia screening was created. As a further action after detection process, it supported reading skills, related to this disability, as well. In this experimental procedure, a set of tests were conducted. In particular, assertive tests were taken place in 4 dyslexics and non-dyslexics to find possible errors, followed by sound interference tests. These searched for the environment noise concerning the reading procedure in the same manner as above. Tests with dyslexics, compared with non-dyslexics was the next step to prove differences in their results of reading recognition. Also, usability tests were carried out to prove some criteria of the instrument (easiness, reliability etc.). These tests resulted in the approval of this mobile app as far as the identification of dyslexic signs was concerned [16].

In Malaysia, also, a cross-platform screening test was constructed, called “DycScreen”, which was available in mobiles, computers and other devices. An instructor, 3 dyslexic and 15 non-dyslexic pupils participated in this study, being asked to answer all questions referred to each section. Even though participants had difficulty in specific evaluations (e.g. cognitive assessments), staying intrigued and willing to take the test through digital devices. In this way, potentially dyslexic children were identified efficiently [17].

In Mexico, a linguistic web-based game was presented, known as “DyTECTIVE”, which could be played, using several digital devices like a mobile phone. The sample was 243 children and adults (95 participants with dyslexia), who participated in this research, playing all game levels after parental consent. Observations indicated that “DyTECTIVE” could be an effective, accurate and easy to access approach of identifying possible signs of dyslexia without special equipment [18].

In Saudi Arabia, a pioneering mobile health framework for any language was presented, aided by auto-grading algorithms to screen possible signs and symptoms of dyslexia. More than 5 dyslexic and 10 non-dyslexic people were asked to take the test for different test modules several periods. The auto-grading was used as a detection approach to categorize dyslexics in a group among the other participants. Significant observations of this process, showed that the form of the features played vital role, since a diverse feature or a detailed and a low-level feature was poor for the identification rate [19].

In addition, in Kuala Lumpur, Malaysia, a mobile application was proposed, known as “Dleksia Game”, making effort to screen dyslexia among children. A usability testing was taken place toward 11 dyslexic toddlers (aged 6-8 years old), who were asked some questions after playing the game. Results showed that the majority of kids were keen on playing this screening game, feeling that it was just a game instead of a detection process [20].

Further, in Quito, Ecuador, a mobile application (“TEDE”) was constructed for the identification of dyslexic kids’ writing and reading disabilities. In this experiment, 11 kids with developmental dyslexia (aged 8-11 years old) were asked to take the test, engaging in items, focused on reversion of complete words and confusing letters by sound at the beginning of the word. The test was completed by users supervised by authorities, teachers and psychologists. “TEDE” had two forms, that were the manual and digital version. Observations indicated that, firstly, all participants were advocates of the digital test form via mobile phone in contrast with the printed test form. Their performances on word recognition tests were the same or better than on paper. Also, the students were amazed at the mobile app. The “TEDE” organized an appealing environment with attractive sounds and colors, enhancing their reading of this aspect of learning (e.g. phonological awareness) and other attributes [21].

In Malaysia, a mobile application was introduced, named “Kiddo Disleksia” to identify dyslexic kids through visual and auditory methods. The effectiveness of this tool was inspected through a usability test towards 20 dyslexic students. Indispensable differences were recorded related to reading recognition and comprehension and the speed in completing activities, when students with severe and mild symptoms of dyslexia were compared. However, the groups were differentiated, giving attention to listening

and spelling skills. According to participants' views "Kiddo Disleksia" was a joyful and useful manner of detection procedure [22].

In Brazil, an alternative digital version of the Rapid Automated Naming ("RAN") was proposed for mobile tools, in order to identify kids' with or without dyslexia reading difficulties at an early stage. An evaluation test was carried out, organizing a public opinion survey in 21 professional speech therapists and education therapists. As highlighted, the new digital version of the test was considered unanimously to be an efficient, fast and easy type of the detection test, which could identify dyslexic students through magnificent utilities and characteristics (e.g. appealing pictures) [23].

In Sri Lanka, a new mobile app was invented, called "Pubudu", so as to screen children with dyslexia, dyscalculia and dysgraphia. In this study, a testing of this app was conducted towards 50 disabled and 50 non-disabled kids. It was obvious that this tool was accurate in dyslexia, dyscalculia and dysgraphia screening at a remarkable percentage [24].

3.2 What mobile smart applications have been designed for dyslexia intervention?

Second classification was addressed to mobile smart applications for dyslexia intervention. This category consisted of 14 studies (53,8%). Several mobile smart apps have been constructed, accumulating supplementary or totally different features and forms.

Specifically, in Portugal, a pioneering mobile application was recommended, with the view to enhancing a dyslexic student's re-educating. In this study, dyslexic and non-dyslexic groups of 4 students aged 10-12 years old were tested in a game usability and functionality testing. The former had the same or sometimes better performance than the latter, interacting with the interface in an easy way. It was a powerful tool for adaptiveness of students' with dyslexia learning environment, as it provided both these children and their teachers with useful feedback about their progress through optimizing their multisensory perception [11].

In Malaysia, a unique mobile comic application was come up with, in an attempt to propose an alternative approach of learning for kids with dyslexia. For this purpose, 7 dyslexic pupils and teachers were interviewed and observed as far as this application usability was concerned. The results came to light that the entire research group was excited, motivated and interested with the special properties of this application, which seemed to be an indispensable supplementary learning advantage. Moreover, participants were able to discern the concept of this kind of story and re-tell it in detail, being encouraged to retain the attention span [25].

Additionally, in Pakistan, a new mobile learning application was designed through a Writers Learning Algorithm (WLA). It was focused on dyslexic toddlers' attributes and preferences, aiming to optimize their preliminary writing skills. A great number of young dyslexic writers from several dyslexia institutions, their parents and teachers took part in this experiment. The application evaluation and usage highlighted that children with dyslexia improved their writing proficiency and overall learning performance as a whole. Indeed, this advanced device was expected to be a potent and valuable educational idea, meeting their distinctive needs [26].

In Moratuwa, Sri Lanka, a state-of-art mobile application was proposed, known as “ALEXZA”, which provided them with the opportunity to confront their reading problems in everyday life. In this research, a preliminary test evaluation of this system was carried out, where a group of 5 students with dyslexia participated. This accomplished testing was focused on indispensable aspects of ameliorating their reading disabilities [27].

Furthermore, in Perak, Malaysia, an application, “CinTA” (Cara Interaktifulis Abjad) was constructed, supporting dyslexic kids’ writing skills and character recognition. In the evaluation procedure, 5 students with dyslexia were chosen. Throughout this implementation of this app, both students and teachers were favored of it. They were interested in appealing and easy to use interactive environment, paying attention to graphics, images, alphabet video tutorial and other features. Most of children with dyslexia were totally focused and activated, achieving incredible and wonderful performance in the learning session [28].

In Malaysia, the first version of an avant-garde mobile application was promoted, called “Dyslexia Baca”, so that children with dyslexia can familiarize themselves with alphabet recognition, reading and memory skills associated with reading. In this study, the “Dyslexia Baca” was evaluated by 7 experts, who were asked to express their opinion about usability problems in the user interface such as difficulties in multimedia characteristics, content, general items etc. It satisfied all these requirements of experts, who came to conclusion that it was a user friendly and attractive well-designed environment. The first edition of this app seemed to support learning in an interactive and joyful way without bounds, motivating each user [29].

In Saudi Arabia, a groundbreaking multimodal interfaced, cloud based mobile-learning tool was proposed, which customize the learning process according to students’ with dyslexia learning profile and needs. The main object was to enhance their educational performances. The evaluation of this multimodal interface tool was taken place, assessing a random sample of students with dyslexia before and after interactive with the it. The participants, feeling contended with the system, made sufficient progress related to the reading skills and learning abilities. It was noticed that it provided useful output and input, appealing presentation, qualitative educational material via several modes, which indicated that multimodal learning interface is a supportive environment for dyslexic students [30].

In Barcelona, a distinctive e-book reader application was presented, known as “IDEAL” that was tailored to dyslexic users’ needs with particular guidelines. Especially for people with dyslexia a distinct option named “DysWebxia” was offered to customize all operations for the provision of appropriate familiar environment and guidelines. These layout guidelines were tested, comparing a group of 22 native Spanish dyslexics with a group of 22 non-dyslexics in a user study. They participated in semi structured interviews and complete a questionnaire and a reading test, which were recorded by the think aloud technique and the eye tracking. Even though the app encouraged them to read many documents due to customizable settings, the improvement was limited to the modification of the design and the manners that a text was presented, including the most readable choices [31].

In Malaysia, a mobile application was produced, named “Mr Read”, with the view to developing kids’ with dyslexia reading. For this purpose, 7 teachers and a student participated in functionality and usability tests. Participants were contented with this tool, admitting that it was easy to use. They were intrigued in navigating, reporting that learning process was efficient [32].

Afterwards, in Malaysia, an enriched version of a previous mobile application (“Mr Read V1.0”) was designed, called “Mr Read V2.0”, with the aim of supporting students’ with dyslexia reading skills. In this research, 4 teachers, 2 parents and 8 students with dyslexia participated. Children, also, took a set of quiz in three experimental phases. Results shown that the majority of participants were satisfied with the interface design such as pictures, colors, clear and appropriate sounds. Also, they admitted that it was such a helpful system for enhancing dyslexic kids’ reading through an efficient learning approach. Dyslexic students’ reading performance and aptitudes were improved significantly, demonstrating the usefulness of the app, which adopted the distinct sight word strategy [33].

In Barcelona, Spain, a mobile game application was developed, named “Dysegxia” to provide useful word exercises for dyslexic kids. A group of 7 dyslexic children participated in a heuristic and preliminary formative evaluations that were conducted, utilizing the think aloud strategy. All kids were in favor of this tool, which was characterized as helpful. They asserted that it was a more attractive way of working on exercises than doing assignments on paper [34].

In Melbourne, Australia, a mobile serious game (“Prosodiya”) was introduced as a distinct intervention approach for German children with dyslexia, which was focused on improving syllable stress awareness related to spelling and reading aptitudes. In this evaluation process of the game, 137 German children with dyslexia or low spelling and reading performances participated, divided into two groups. They were allowed to play the game at home during a particular period of time and then they were asked to complete a questionnaire, assessing literacy skills in class. Participants were keen on fantastic environment of the game, cheerful pedagogical agents, rewards and helpful tutorials for easy navigation. The children were fervent supporters of the tool, which were interested in unique properties [35].

Moreover, in Greece, a state-of-the-art mobile application was constructed, called “EasyLexia”, to support students’ with learning disabilities in learning process. In design and evaluation procedures 5 parents and 10 students with learning difficulties took part. Specifically, in evaluation process children navigated in app with or without supervision. The findings indicated that students were eager for interacting with application. They completed tests, which aroused their interest. Most of the participants made progress in phonological decoding and recognition, feeling the learning procedure like a game [36].

In Brazil, a new mobile game-based application was developed as a different treatment method for dyslexic students’ usual difficulties in three domains (visual, auditory and working memory). A usability test was conducted among 10 children, accompanied by speech therapists. Results demonstrated that this app seemed to be efficient, motivating and encouraging children through awards. It supported their needs, endorsing adequate and constant learning [37].

3.3 In what dyslexia symptoms mobile smart apps have been mainly focused for screening and intervention?

According to the findings, 7 studies (58,3%) out of 12 referred to mobile smart applications for dyslexia screening, which detected several symptoms of dyslexia (motor skills, attention and concentration problems, mathematics, direction time, phonological processing, listening, spelling, reading, writing, visual perception, working memory and other vision and cognitive skills). The remaining 3 (25%) papers reported mobile smart apps that screen only reading disabilities. The final 2 (16,7%) studies reported mobile smart apps, which screen both reading and writing difficulties.

According to results, 9 (64,3%) papers proposed mobile smart applications for dyslexia intervention, which supported students' reading difficulties. Specifically, 6 studies presented mobile apps that were mainly focused on reading. The other 3 studies introduced mobile apps that assisted reading problems in comparison with other language difficulties (writing, spelling). The 3 (21,4%) papers referred to mobile smart apps, which enhanced a range of problems (educational performance, visual memorization, visual auditory, working memory, short term memory, concentration and cognitive skills, mathematical logic) Some of them (2 studies) supported reading as well. The remaining 2 (14,3%) papers introduced mobile apps to support writing skills.

4 Conclusion

In conclusion, the identification of dyslexic population and a well-designed intervention program are the most indispensable prerequisites for overcoming dyslexic difficulties. According to the research data, a significant number of mobile smart applications have been proposed between 2018 and 2019 (especially in 2018). This finding was consistent with research, as mobile smart devices are increasingly used during the last decade, becoming so popular [38], [2], [39]. These researches were published in different countries (e.g. Malaysia, Spain, Brazil, Sri Lanka, Greece, Australia, Equator etc.). A greater proportion of these studies described the construction procedure and related empirical researches or pilot studies or usability, functionality, evaluation test for mobile smart apps for dyslexia intervention, compared to mobile smart apps for dyslexia screening. Specifically, 14 out of 26 papers referred to mobile smart apps as a tool for dyslexia intervention. Indeed, research reveals that mobile learning is more efficient in the individualized and integrated lessons in a mobile app [39]. This prospect provides learning opportunities for young population, including dyslexic students, who might make progress. The majority of these apps addressed primarily to difficulties related to reading. According to research, reading problems are a common difficulty for dyslexic students. [40]. Nevertheless, studies about mobile smart apps for dyslexia screening detected several dyslexia symptoms. Also, future work should give emphasis on the identification of the characteristics for the proposed mobile smart apps, that make them appropriate for dyslexia screening and/or intervention. Other difficulties related to a dyslexic student's disabilities need to be inspected in detail. In other words, data for mobile smart devices, which are oriented to support different aspects of this disorder (e.g. attention, working memory etc.), should be extracted. The results of this literature

review are expected to be encouraging, referring to a wide range of mobile smart applications for dyslexia detection and intervention. Obviously, a mobile app may be used as a supplementary tool, combined with other methods for this venture.

5 References

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