A Review on ICTs, E-Learning and Artificial Intelligence for Dyslexic's Assistance

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Abstract— **This paper is a review on the exploitation of the Information and Communication Technologies (ICTs) on the diagnosis, intervention and assistance of learning disabilities and especially on dyslexia. Here are presented several studies that include computerized techniques or developed applications for adults and children with dyslexia. Special focus is given on individualized approaches in the areas of diagnosis and intervention. New technologies on general or special areas, such as fuzzy systems, artificial intelligence etc. offer direct observation, measurement and qualification of the subject so they are incorporated on designed software for diagnosis, screening or intervention. Here are presented, studies on learning disabilities (dyslexia in particular) that have been realized so far by researchers who have done global research in the educational community. These studies seem promising through technological progress on the areas of psychological assessment, diagnosis and intervention.**

Index Terms— **Icts technologies, dyslexia, diagnosis, intervention, assistance, learning.**

I. INTRODUCTION

This article constitutes a research study pointing out the assistive role of ICTs on a learning disorder (dyslexia) in the areas of diagnosis, learning assistance, intervention, multimedia, web and e-learning technologies. According to the European Dyslexia Association Definition [21], dyslexia is the difficulty in acquiring reading, spelling and writing skills that are neurological in origin. The cognitive difficulties that cause them can affect organizational skills, calculation abilities or even combination of difficulties in phonological processing, working memory, rapid naming, sequencing and the automaticity of basic skills. There is no connection with a person's level of intelligence, individual effort or socio-economic position. However, the diversity of languages and the multilingual demands as well as socio-cultural backgrounds and educational opportunities are a great influence.

Concerning dyslexia diagnosis, certain studies focused on the analysis of specific brain areas, such as the thickness of Cerebral White Matter and the anatomy of Corpus Callosum. Moreover, studies on intervention focused on working memory, phonological awareness, writing-reading-spelling skills and phoneme discrimination. Although intervention is considered to be a form of assistance, we thought it might be presented as an independent category from learning assistance because applications were developed for precise deficits of dyslexia and used for the progress of a certain skill.

The assessment of multimedia, mobile tools and web applications during the learning process was significant. The interaction and multi-sensory technology trigger the interest of the users and give them the appropriate motivation to use them. The difficulties they confronted on synchronous learning and e-learning environments were investigated and having taken helpful approaches into account, they made the access for dyslexic users easier and they developed more personalized environments, which were more user-friendly.

Researches about learning assistance presented applications that were computer based and they offered personalized functions, special word processing environments, customized presentation of reading materials and the opportunity for users to make changes on the text. Moreover, in order to provide support in spelling issues, spelling checkers and multimedia environments were proposed.

During this research an attempt was made to present the crucial role that ICTs play in dealing with dyslexia. While intervention is personalized, people with dyslexia can approve their post cognitive abilities and overcome literacy or social difficulties. There are two important parameters related to intervention. Firstly, the way traditional techniques were adapted and computerized in the field of ICTs, and secondly, the design and development of completely new tools and techniques. By using these applications and by following these techniques, people with dyslexia may take part in the learning experience, have their self-esteem raised and may improve their psychological state. Finally, this relation between ICTs and learning disabilities may affect other scientific areas such as education, psychology and social science.

II. DYSLEXIA SCREENING AND DIAGNOSIS

A. Brain analysis –based Diagnosis

In order to have a better diagnosis of dyslexia, certain studies have been conducted in dyslexic's brains [1] [2]. Neuropathological studies have revealed an abnormal anatomy of the cerebral white matter in dyslexic brains and have examined the quantitative shape analysis of CWM (Cerebral white matter) gyrifications on 3D Magnetic Resonance Images (MRI). Their approach consists of the following steps: Segmentation of the

CWM on a 3D brain image using a deformable 3D boundary, extraction of gyrifications and shape analysis to quantify thickness of the extracted gyrifications. After the results have been gathered there is a separation between dyslexic and non-dyslexic people, which appears to be a very useful tool for analysis.

At the same time, an analysis of the brain cortex is used for the early diagnosis of dyslexia. More precisely, a spherical harmonic analysis for the 3D surface of the brain supported by the unit sphere combines the special basis functions (spherical harmonics - SHs) [3]. This type of analysis is carried out in the following steps: 3D brain cortex segmentation, construction of the 3D mesh model of the brain cortex surface, mapping of this model to the unit sphere, computing SHs on the surface and determining the number of SHs to delimit the brain cortex. The classification of dyslexic and non-dyslexic brains is possible, by using this description of the brain shape complexity with a new shape index.

B. ICTs-Based-Diagnosis

A computerized test has been developed, for the most accurate pre-school dyslexia screening diagnosis, the DEST test [4]. Since theoretical diagnostic tests fail to define dyslexia before a child is able to learn to read, early age diagnosis is achieved by using carefully designed tests on information which are designed to be independent of reading. Furthermore, new generation computers extract objective and reliable results, which with carefully designed programs, prove to be valid, in the sense that they reflect the results obtained by the traditional methods.

A research involving visual stress (unpleasant visual symptoms experienced when reading) has reported a connection with dyslexic persons, which remains irrelevant [5]. They have presented ViSS, a computerized visual stress screener that includes reading-like visual search. Dyslexic children are found to have significantly higher susceptibility to visual stress as well as critical and non-critical symptoms. In addition, visual stress has been found to possibly appear more often to children with dyslexia rather than to children without.

Another systematic approach for identification of dyslexia in childhood and the classification of potential cases more accurately and easily, is by using Artificial Neural Networks [23]. Due to the variation of symptoms of dyslexia in other domains except for literacy acquisition, the conventional diagnostic techniques fail to diagnose dyslexia accurately. According to this technique when using MLP (Multi layer perception) neural network architecture for the proper classification, and the input of evaluation tests including testing of reading ability, phonological coding skills, and an IQ test, a successful discrimination between dyslexic and non-dyslexic individuals is achieved.

For diagnosing dyslexia in early childhood, children have to solve a non-writing based graphical test [24]. Experts have estimated that the results can cause conflicts as certain symptoms are compatible with more than one disorder and artificial intelligent techniques is a complex task with multiple sources of uncertainty. In order for this test to become more accurate, as far as genetic systems can exploit the information in uncertain data sets, a linguistically understandable, rule based classifier has been designed using a genetic cooperative algorithm. This algorithm is a part of a web based pre-screening application. Parents can use it when they observe a symptom and consult an expert for further examination.

III. DYSLEXIA INTERVENTIONS

A. Computer-Based tools

There is great interest on how educational technology may assist phonological awareness that may persist despite intervention [6]. For this cause a hypermedia application was developed (PHAES) 'Phonological Awareness Educational Software', to help dyslexic readers, providing them with phonological awareness training. It has also been designed to be attractive to children, with simple graphics, to avoid cognitive overload, to have simple navigation and to be able to run on any computer. In addition, it can be used with or without supervision as the age group is not strictly defined and it can be a useful and supportive tool for teaching. This application has proved to be educational and is an example for further research in the area.

Heredity concerning dyslexia appears to be a factor and therefore a study examines early prevention during pre-reading ages [7]. Therefore, pre-reading children genetically at risk receive a home-based and computer assisted training on phonemic awareness and letter sound relationship, which has been based on the 'Word Building' technique, originally developed by Beck. These children improve their reading skills more than children without familiar risk who have also received extra training, and who kept up with the normal development of phonemic awareness more than untrained children with familiar risk. A conclusion to the above research is that in order to achieve the best results, home and school based training till the first grade is advisable.

B. Digital media

An examination of dyslexia rehabilitation based on DTV Digital Television has been presented and addressed to Italian children [8]. This is a kind of ICTs based service for people who have neither Internet access nor the needed skills to use the Internet but are familiar with television. T-islessia is a T-health project involving six year old children at risk of dyslexia, performing rehabilitation exercises on a daily basis, whether they are at home or at school. This project has developed an interactive service named 'Magicabra', which delivers highly interactive games in order to develop reading and writing skills. Results have been positive enough as the more interactive the sessions, the higher the level of acquired skills.

There is further examination on the effects of computer based media on learning outcomes of individuals who have dyslexia in the UK [9]. The research has been based on DCT (Dual Code Theory) whose common area with dyslexia is inefficient working memory. Processing results have found that, different

combinations of media have led to significant differences in the understanding of dyslexic learners.

C. E-learning and dyslexia

If someone reads an introduction of Special Education Needs and Disabilities Act (SENDA), it is easily understood that learning web sites and learning material must undergo reasonable adjustments in order to facilitate people with learning disabilities [10][11]. Therefore, an investigation has begun regarding how e-learning and online learning activities deal with problems for students with dyslexia beyond accessibility and web design. This research consists of three main stages: theory building, theory testing and theory extension. Results have proved that students with dyslexia encounter problems with synchronous learning activities such as reading, spelling and sentence structure, transposition, memory, organization, time management and lack of confidence.

Taking into account the fact that people with dyslexia encounter certain difficulties concerning e-learning activities, there is a study [12] which was developed in a personalized e-learning environment that supports dyslexic pupils. The framework for producing a computer based personalized environment has the following characteristics: implementation of phenomenological approach to learning, adaptation of the learning process to dyslexic pupils, learning activities that focus on obtaining reading ability, learning activities with learning resources and collaboration capabilities for e-learning environment production. This framework enables educators to have the freedom to compose a variety of units of learning by combining learning materials from all available databases and applying certain models.

Another research has developed a framework of adaptable e-learning environment in order to achieve personalized e-learning facilities for dyslexic pupils [22]. It is an open agent-based framework that supports automated ontology-based learning facilities production composition and use, as well as management reuse and retrieval of external resources. It includes Knowledge expert agent, Teacher agent, Dyslexic learner personal agent, Collaboration agent, Evaluator agent, ontology search agent, Web search agent, Mapping, Annotation agent and External resource agent. Conclusively, this design of a reuse platform ensures an effective and efficient e-learning environment, as it uses capabilities of semantic and agent-based technologies so as to achieve flexibility and semi-automation.

D. Games, Multimediatools and web

Certain researchers have used multimedia elements as a main part of strategies, activities and environment and have developed a multimedia based Learning Object, namely IMLO (Interactive Multimedia Learning Object) [13]. Its methodology has been adapted on a think-allowed protocol, which triggers users to think aloud as they perform a set of specific tasks. Its main idea is to deliver this topic in an interactive story-based form. Its usability has been tested among dyslexic children and qualitative approaches have been used. The results are good enough as their aim is to understand the use of multimedia elements in the field of dyslexia with regard to learning support.

A research on computer-based learning games has given the potential to dyslexic students to overcome certain difficulties and their lack of motivation [14]. The level of this influence depends on the software that has been developed and its adaptation on individual needs. A project has been developed named Caldys2, containing a suit of activities that could be used to teach the English language to non-English dyslexic learners. As there is no evaluation method, Learning Games Education Evaluation Rubric was developed, which consisted of 19 questions based on learner interface, pedagogy, sustainability and technical aspects. The aim of this project was to build effective learning software for all learners with or without dyslexia and this was successfully realized.

IV. LEARNING ASSISTANCE

A. Reading Assistance

Children with dyslexia have special learning skills and most of the time only specialized institutions can support their reading difficulties. Therefore a study [15] on reading support began, and software has been developed, the AGENT- DYSL, which affects learning process. This system proposes a reading system for dyslexic children with personalized attention, through customized presentation of reading materials. In order for it to be more acceptable it employs age-appropriate and dyslexia-sensitive user interfaces, it integrates into school environment and takes into account the context of learning. The main difference with other software programs is personalized assistance. It is proved to be really helpful for children with dyslexia, as it combines speech recognition, state recognition via image and error type profiling via adaptive and personalized support.

Since reading is a rather important issue for people with dyslexia, an Intelligent Tutoring system project has been developed [16], the R^2aft tutor (Repeated Reading Adaptive Fluency Tutor) the purpose of which was to improve reading fluency among students with dyslexia. It educates students on appropriate decoding patterns and motivates them. Initially, the TASA (Text And Story Assembler) was created, which is an engine that generates a text to be read. TASA is a set of facts and rules in the Clips expert system shell (by Giarratano and Rilley) and includes three types of facts: user-model, story-world and lexicon. A second point is that motivation is generated by the interactive story that is created and enables students to make plot choices that affect the unfolded story. Its usage is effective for students with dyslexia although further attempts for evaluation of the system are planned for the near future.

Studies on implicit learning abilities for dyslexic subjects have been rather ambiguous. A new study [25] tries a different approach that is to examine implicit learning abilities involving motor system, using the serial response time task (SRTT) and artificial grammar learning (AGL). On the one hand they are quite different

concerning motor requirements and the main role of cerebellum for learning, and on the other hand they are similar to the cognitive process which is involved in implicit learning. Tests are conducted to native German adults in two groups of twelve dyslexic and non-dyslexic people. Researchers have used standard neurophysiological tests of reading ability, attention and executive functions, to identify the possible differences in basic process of SRTT and AGL. Then SRTT tasks follows, during which participants are exposed to a structure display and learning is measured by response time (RT) in a structure sequence with RT to a random one. As for AGL, letter stings follow a markovian finite state grammar and participants have to judge new letter strings according to their grammar structure. The findings above conclude that implicit learning in dyslexia is an intact characteristic which possibly has to be regarded when training programs are developed.

Following the previous research, another one on implicit learning has been developed this time for primary school children (9-12 years old) with developmental dyslexia using artificial grammar learning AGL (task) [26]. The groups tested comprised of children with dyslexia and typically developed children as developmental differences between them could affect implicit learning. Two AGL experimental conditions are examined, due to the fact that students with developmental dyslexia have been reported to associate deficit to explicit and implicit processes. The first experiment focuses on implicit instructions and the second experiment on explicit instructions. In experiment one the group of typically developing children has been affected and in both experiments a grammatically progress has been noted. As a result children with developmental dyslexia failed to give evidence to AGL performance as it may intervene between cognitive developmental factors.

B. Spelling Support

There have been several studies concerning spelling support for people with dyslexia. One of them presents a software system, which is a spelling checker for dyslexic writers, named BABEL [17]. It can cope with multiple errors and includes a model of each user's spelling patterns. User model operation is based on the production of rules and is familiar to Young's and O'Shea's example. According to this approach only mal-rules are modeled and derived from the cognitive model of Patterson and Shewell. They are more complex and describe transfers of errors made by dyslexic writers. Using choices made from a list of suggestions as feedback, researchers have measured and improved the accuracy of the system. Evaluation and testing have concluded that there is successful correction and detection of errors and user model allows correcting diverse errors more effectively.

Another development of a computerized environment for dyslexic children has been presented, [18] which encourages them to construct their own rules for the words they have spelling problems with. This research is based on the SelfSpell environment which allows the integration of text, graphics and synthesized speech in

addition to the capability of the interaction of 'point and click'. The main aim is for the child to be able to use it without help most of the time, with partial support from a parent or from a teacher. Therefore, a program within the environment has been developed where all buttons are programmed to 'say' their name triggered by the mouse pointer and some highlighted words are also pronounced by a speak button. After the evaluation of groups of children with dyslexia of average age 13 years, it was found that this is a motivational and effective program with improvements in spelling.

C. Mathematical Skills

Since dyslexia is considered a cognitive deficit, certain researchers have begun the construction of tools facilitating learners with dyslexia. This research presents the design of cognitive tools for the better performance on mathematical tasks [19]. Since these tools have been developed, tested and incorporated into an online tutoring environment, 'Spatial Math Tutor'. Its main novelty is the 'face-to face' interaction which has been proved beneficial for children with learning difficulties. Elementary school students with diagnosed dyslexia have been facilitated by the graphical representation of the SMT and the manipulation of CG objects. SMT can be a beneficial tool for encountering difficulties on mathematical skills for users with dyslexia, taking into account all the assistive 3D graphic technology and interaction tutoring.

There are not only difficulties in reading, writing or spelling for dyslexic students, but mathematical issues too [20]. A study has been conducted on the most appropriate assistive technologies for terminology, symbolism and graphic representation concerning mathematics. The main idea is the development of a tool that allows users to read technical and scientific documents, understand the spatial structure of formulas and matrixes and produce papers with technical and scientific content. The appropriate text language that researchers used is LaTex. Additionally with a LaTex parser, each mathematical object can be associated with its match in mathematical language, using a speech synthesizer. Finally, this software proves to be really helpful for school homework and really facilitates both teachers and students.

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