

Assistive Technology for reading disabilities: opportunities for developing countries

Tania Cerni & Remo Job

Department of Psychology and Cognitive Science,
University of Trento, Italy

Abstract

An "Assistive Technology Device" consists in "any item, piece of equipment, or product system, whether acquired commercially, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" (Assistive Technology Act, 2004). This kind of technologies in the schools setting is not only useful but often indispensable to allow disabled people to reach their educational goals.

Objectives. In this paper, we review how assistive technologies can be a powerful means for people who have reading difficulties and in particular dyslexic children to meet their particular problems. Furthermore, we analyze their use in educational settings in Developing Countries focusing on opportunities and problems in these particular contexts.

Materials and Methods. We analyzed a set of devices and programs specifically built to help dyslexic children or adapt to their deficits, providing a description of these technologies and practical examples. In the analysis we took into consideration several factors, including the integrative and support roles of Assistive Technologies in building inclusive educational settings (see e.g. Hasselbring, Bausch, 2006). We also investigated educational and sociocultural problems and opportunities related to dyslexic people and available technological faced by Developing Countries.

Results. We analyze separately compensatory technologies and rehabilitative technologies for dyslexia. Compensatory technologies - like text to speech software, voice recognition and orthographic editors - consist in computer applications that help dyslexics to access the content of the different subject matter, despite their difficulties, while rehabilitative technologies are devised to develop and strengthen reading, from the basic orthographic units to words reading and text comprehension - thanks to specific reading trainings. The key feature of rehabilitative technologies is their reliance on combined educational and motivational goals through animated and game-like apps to help children to improve their reading skills. In general, technologies that rely on multidimensionality and allow fine-grained integration of multisensory information of different sensory modalities and through different media seem to be the most effective. Thus, the rapidity of information processing and large memory size, proper of technologies,

can be used to compensate difficulties in these processes, proper of dyslexia. Finally, technologies may increase motivation and curiosity, alleviating learning difficulties and fatigue, and they may also be functional in stimulating need for autonomy by encouraging an active role during learning in and out of the classroom. Unfortunately, economic, technical, and sometime cultural problems mitigate the positive role of assistive technologies in the Developing Countries.

Conclusions. Technologies are useful tools for helping children to both acquire reading abilities and to overcome some of the problems typical of developmental dyslexia and reading difficulties. A challenge for the educational setting is to integrate such technologies into the educational practice, and for technologies to be tailored to the need of the individual learners. In addition to these, the use of such technologies in the Developing Countries faces obstacles of various kind.

1. Introduction

Informatics changes and the large diffusion of technologies impact on the educational environments by increasing the need to promote not only literacy acquisition but also the acquisition of the so-called informatics literacy (Cummins, 2002). The motivation is twofold: on the one hand, having a basic knowledge in informatics and technology use is indispensable in most learning and work environments, as well as in human communication; on the other hand, technology requires individuals to keep abreast of innovations and may help in specific situations

Regarding this second aspect, Assistive Technologies (AT) have an important role in helping the clinical rehabilitation of disable people and in offering tools finalized to overcome their deficits. As reported by the Assistive Technology Act (2004), an "Assistive Technology Device" consists in "any item, piece of equipment, or product system, whether acquired commercially, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities". Technologies can adapt to the disability and its evolution and offer support during educational and work tasks and during social and cultural life (Alper. Raharinirina, 2006).

The Assistive Technology Act (2004) pays particular attention to the educational application of AT, as assistive devices are oriented to the empowerment of programs and activities devoted to education, rehabilitation and training in general. The assistive device has to be adapt to the development of disable people and to the entire individual path. Therefore, an AT has an essential role in the acquisition of those skills that guarantee independence during life. This kind of technologies in the schools setting is not only useful but often indispensable to allow disabled people to reach their educational and individual goals in the same manner as their peers, promoting integration, shaping learning style and simplifying social participations (Alper. Raharinirina, 2006; Martin et al., 2009). In this sense, the use of technologies in the educational context should not be considered as a sign of diversity but, rather, as a tool finalized to the acquisition of knowledge and autonomy.

In this paper we focus on the central role of specifically-built AT for people who have reading difficulties and in particular dyslexic children. We will analyze why technologies are functional to overcome the typical linguistic and comprehension problems encountered by dyslexics and how they can help these children in reaching autonomy in learning and in integrating them into the class environments.

To conclude we describe the thorny issue of the use of AT for dyslexia in the educational setting in Developing Countries focusing on opportunities and problems encountered by AT in these particular contexts.

2. Assistive Technologies for reading disabilities

Clinical interventions start once the reading disabilities is diagnosed and, usually, they provide ad hoc educational strategies for the specific difficulties encountered by the child. If and while these difficulties are not overcoming, the child needs to develop/adopt procedures that are different and alternative to those classically used for reading and writing. Assistive technologies are powerful from a rehabilitative point of view, by supporting the child in reading and writing acquisition, but also from a compensative point of view, by offering alternative methods to traditional reading and writing. Therefore, technologies for dyslexia can be classified into two main categories that are not mutually exclusive but present some degree of overlap: *rehabilitative technologies*, devised to help dyslexic children to strengthen and improve their linguistic abilities by providing specific rehabilitative trainings, and *compensative technologies* that comprise those devices developed to help the child to overcome the deficit and to have access to grade level texts (see e.g. Hasselbring. Bausch, 2006).

Rehabilitation and compensation are two key factors in the relationship between dyslexic people and technology and have to be considered in parallel. Specifically, the designed educative program should include one or more of the standard procedures but also the use of technological devices that can be helpful in rendering effective the rehabilitative programs. But compensative technologies should also be employed in order to provide alternative paths to acquire the content and knowledge need for his/her school success and social well-being. Thus, compensation is an auxiliary, and not a substitutive, tool for education (Hasselbring. Bausch, 2006).

2.1. Rehabilitation and compensation: analysis of AT for reading disabilities

In this paragraph we provide a detailed description and some examples of rehabilitative and compensative technologies for reading disabilities. We aim to show how technologies are a powerful means in treating dyslexia and in supporting learning. Furthermore, we discuss the advantages of the introduction of technological tools in the rehabilitation and education of dyslexic children.

2.1.1 Rehabilitative technologies.

Since rehabilitative technologies are meant to train impaired

linguistic abilities, it is useful to consider briefly the main linguistic problems involved in dyslexia. The debate on the causes of dyslexia is still open. Despite the different, sometimes opposing, hypotheses about the underlying mechanisms involved in substandard development of reading abilities, there is wide agreement about the central role of phonology, seen as a cause or as a consequence. Specifically, dyslexia are characterized by a deficit in the representation and use of phonological information and in the memorization and recovery of such information (e.g. Ramus et al., 2002)), either because of poor phonological representations (e.g. Ramus. Szenkovits, 2008; Castles. Coltheart, 2004) and/or deficient segmentation of speech units (e.g. Hachmann et al., 2014). Many linguistic activities are automatic, and should be rapidly and precisely executed with little or no conscious planning and control. This means that oral and written language comprehension is possible when articulation, acoustic recognition and grapheme-phoneme conversion processes are automatized. While children with a typical development automatize reading processes, dyslexic children experience difficulties in one or more of these processes. Therefore, dyslexic children need an individual educational program that helps them in the acquisition of the basic rule or reading and writing. Most popular treatments for dyslexic people are focused on the acquisition and automatization of decoding abilities, a set of processes dyslexic children have problems with and whose faulty execution are the first sign of an impairment of reading and writing.

In this section we report examples of some of the software developed for the specific trainings for dyslexia and underline how ATs are powerful tools in integrating traditional rehabilitative programs. Such technologies are commonly dedicated to different stages of reading acquisition, depending on the age of the children, but also on the different skills that are necessary to become a skilled reader. According to many models of reading acquisition, learning to read requires the development of two main paths for translating orthographic information into phonological (for reading aloud) and/or semantic information (for silent reading): the grapheme-to-phoneme conversion (gpc) path and the lexical path (see, e.g. Coltheart et al, 2001; Perry et al., 2006). Different ATs can be categorized on the basis of the linguistic mechanisms that they are designed to train. We will provide a brief description of both reading paths, with the involved linguistic mechanisms, and the corresponding impairment in dyslexia. We will then report examples of rehabilitative technology for the assumed-to-be-impaired mechanisms. Finally, will discuss some issues related to text comprehension.

The phonological path. The grapheme-to-phoneme path constructs a phonological output by means of the application of grapheme-phoneme conversion rules specific for each alphabetic language. Thanks to these rules, words are processed by the visual system and each letter or letter clusters corresponding to graphemes are assigned its corresponding sound. Children learn the systematic relationship that exists between the written and oral forms of letters

and letter clusters and how to merge sounds into phonological forms corresponding to words in their own language. As a further improvement child apply phonetic rules also to groups of letters, as syllables. Through this path, children may be able to learn to read most monosyllabic words, even unfamiliar word and non-words, by means of assembled phonology, without semantic mediation (Coltheart et al., 2001).

The capacity of identify spoken sounds, known as phonemic awareness is a key factor for reading acquisition, and is considered an important precursor of reading abilities (Ehri et al., 2001). It is linked to the development of the phonetics capacity thanks to which children learn to discriminate phonemes, understanding their differences during the perception of spoken language. When children start to speak, they develop cognitive representation of phonological aspects of language becoming aware that words can be segmented into letters, syllables and the corresponding sounds, and that different words are the product of the combination of a limited number of linguistic elements (Shaywitz. Shaywitz, 2006). The phonological deficit common in dyslexia may adversely affect the acquisition of grapheme-phoneme conversion procedure indispensable in reading in alphabetic systems.

Rehabilitation programs tapping into these mechanisms important, and there several ATs dedicated to the acquisition of phonemic awareness principles and phonemic synthesis.

An interesting example of software in this area is MyLexics, by Abdullah et al. (2009). This software has been developed to teach reading and writing to dyslexic children in the Malaysian language, and is based on the the Paivio's dual-coding theory (see, e.g. Mayer. Sims, 1994; Lotto et al., 1999). This theory proposes that learning entails building knowledge encompassing different modalities, and that utilizing different sensory modalities can make learning very powerful.

MyLexics provides for three modules: Abjas (alphabet), Sukukata (syllables) and Perkataan (words) proposing a progressive training from letters and decontextualized syllables to syllables to words. In Abjad, the software pronounces and draws the letters offering the possibility to the users to follow the tracing with the finger. During this phase, basic rules of letters-phoneme conversion is trained. Furthermore, the possibility to listen, to associate an image and to follow the drawing with the fingers is an interesting feature to improve memorization through multisensorial, i.e. through oral, visual and tactile experience.

The Sukukata module is aimed at teaching children to combine letters into syllables through appropriate animations: the child can click on the syllable, listen the corresponding pronunciation and watch an animation of the combination of letters. Learning is possible thanks to the different sensory modalities involved and the designed animation that capture attention and stimulate concentration.

Finally, Pakataan trains children to learn words with similar syllabic composition through the combination of syllables presented in

different colors. Like the other modules, also this module presents texts, images and audios. In particular, images of the words' referent are presented to build a strong association with meaning.

Another interesting software is Chassymo (Ecalte et al., 2010). Designed for French dyslexic children, the main purpose of this software is to train phonological abilities and the assembly route through audio-visual training. The language-specific characteristics of the software have been pointed out by the authors who maintain that in French intensive trainings in grapho-syllabic segmentation are more powerful in improving word recognition than grapho-phonemic trainings (Ecalte et al., 2013).

Chassymo comprises exercises based on grapho-syllabic word processing. On each trial, the syllable is first presented orally (500 msec) and then visually (500 msec), followed by a word. Children have to click on the number that corresponds to the position of the syllable in the word (initial, median and final) or to an extra button when the syllable was not present. Furthermore, there is the possibility to click on the help button that allows to visualize the word with the highlighted syllable.

The evaluation of the software on 2nd grade children with and without dyslexia showed that the software increased word reading more than the grapho-phonemic training. Also, the training improved other linguistic abilities as well, namely silent word recognition, word reading aloud and reading comprehension.

The lexical path. Learning to read requires also the development of the lexical path. This path allows phonological form to be derived from the direct access to the orthographic lexicon, a representation system that specifies the orthographic representation of words and maps them into their phonological form for output. The path also allows access to the semantic system, that makes available semantic information about words. Using this path, readers can correctly pronounce irregular words, which do not follow grapheme-to-phoneme correspondence rules, and non-homophonic homographs (e.g. Coltheart et al., 2001) on the basis of the semantic context.

The architecture of the lexical path is critical for the development of fluency in reading. Fluency is not only the capacity of read accurately but also rapidly and with a good comprehension of what we read (Shaywitz, Shaywitz, 2006). Therefore, the sound-symbol association and the recognition of words are fast and automatic. Young good readers are able to read 100 words per minute (adults read 300), whereas poor readers are slow even when they become accurate (Moats, 2001). Efficiency in decoding skills is important for reading: If a text is read in a slow and laborious way it is difficult to comprehend and to remember what has been read.

Treatments concerning the lexical path comprehend trainings of lexical access finalized to the rapid recognition of words through the activation of visual and semantic strategies. Technologies are helpful in this sense because they allow to control automatically words

presentation.

A method that has shown interesting results in enhancing reading fluency is the Rapid Serial Visual Presentation (RSVP) procedure. RSVP allows to dynamically present a text on the screen (Mills. Weldon, 1987) simultaneously controlling for speed, location, and size of linguistic units. Specifically, text – single words or short sentences - is presented in rapid succession in a fixed location of the screen with the purpose of avoiding saccadic eye movements during reading.

A software suited for helping dyslexic children that combines RSVP and a personalized control of text presentation, is **AirBook**. This device is especially designed for dyslexics and, in general, for people with visual and upper-body disabilities. It consists of a computer, a monitor and a tabletop interface as mobile pads. AirBook is devised to adapt to the reader emphasizing personal control of reading speed and of text presentation thanks to two force-free sensors, able to read proximity of hands/fingers that slide along or above the tablet. One of this sensor allows to control the speed of text presentation, the other sensor offers self-control system parameters like moving between text parts, choosing the text to read, setting bookmarks, setting font size, style and color contrast (Back. Szymanski, 2001).

Text comprehension. Fluency is crucial in text comprehension and this latter is indispensable to be a good reader. Text comprehension relies on a number of abilities and mechanisms, including a vocabulary of adequate size and the building-up of the orthographic lexicon. The former allows for a fine and specific appreciation of subtle differences in meaning, and for a richer lexical network that support comprehension. The latter allows for fast and easy decoding of the text.

An interesting and promising program dedicated to improve fluency, vocabulary, and text comprehension of less able readers is **READ 180**, a technology-based reading intervention program designed for older students, specifically those in grades 4–12 in USA. READ 180 provides helpful tools to help students in reading and texts comprehension integrating different sensory modalities and strategies and providing individualized instruction targeted on the reading level and reading deficiencies (Hasselbring. Bausch, 2006). For example, before reading a test, the student can view a video that provides a background to understand the text. When the text is presented the student can receive help in decoding words and sentences thanks to an automatic text reader. Furthermore, problematic words are trained providing decoding, pronunciation, spelling and segmentation of that words and, if necessary, a translation in another language. At the end of text processing, both comprehension questions and a summary of well-read words are provided. READ 180 shows promising results in improving reading proficiency of poor readers (for a detailed overview see, e.g. WWC Intervention Report, 2009; 2010).

2.1.2 Compensative technologies.

Compensative technologies are meant to provide means to compensate difficulties when the basic processes of reading have been acquired. While dyslexic children may reach some level of ability in reading and writing, they may not be able to process written language easily and automatically; they may use well one of the paths but may encounter difficulties using the other path; they may still lag behind when some mechanism or operation are required. In all these cases, reading, and consequently comprehension, remain difficult, laborious and slow. Therefore, compensative technologies may play a role in sustaining dyslexics during their linguistic development. In this sense, insufficient abilities in words decoding can be a barrier but this should not prevent knowledge acquisition, and compensative technologies may provide ways to access texts and to create texts in autonomy, without the help of a mediator, by offering alternatives to classical reading and writing through oral presentation and images or videos or by providing specific feed-back when errors occur.

In this section we provide a categorization and some examples of compensative technologies.

Reading. The main way reading difficulties can be compensated is through listening. Technology designed to translate a written text into an oral text is called vocal synthesis or text-to-speech software. This special software designed for reading disabilities allows the users to have control over several parameters of the texts processing facilitating them to follow the written text while they are listening the corresponding oral presentation. In this sense, a correct translation of the text into an oral presentation can be compensative but also rehabilitative. Several studies showed an improvement in fluency, lexical and phonological competence, comprehension and concentration when using text-to-speech software (Raskind. Higgins, 1999; Andersson. Draffan, 2005; Higgins. Raskind, 2005; Izzo et al., 2009; Stodden et al., 2012). These technologies can also assist students in the revision of their own written production improving their abilities to detect errors (Raskind. Higgins, 1995; Rao et al., 2009).

Quicktionary Reading Pen II is a portable text-to-speech software produced by WizCom Technologies, Ltd. It is similar to a pen with a small screen where text is visualized. With this pen it is possible to scan texts or single words transporting them from paper to digital format. Scanned words appear on the screen for 1 to 3 seconds and are read aloud by a synthesized voice. The user can set up velocity and volume. The advantages of this device are the possibility to scan portion of texts depending on the need of the reader, the integration of definition, synonyms, and translation of unknown terms, and the possibility to spell and highlight single words and letters. Furthermore, the portability of the system and the low cost make this pen easy to use in different situations and by almost everyone. It has been shown (Higgins. Raskind, 2005) that this device can increase comprehension abilities of young dyslexics (10 to 18 years old).

Another interesting example of compensative software

designed for dyslexia is **AGENT-DYSL**, an intelligent system to assist reading. Children that use this system receive a personalized attention thanks to the presentation of texts suitable for their reading level and functional to their reading improvement. To personalize the interaction, the software is integrated with a speech recognition system and face analysis service. For the evaluation of reading abilities, the user reads aloud a text presented by the software while the speech recognition system processes the speech signal and analyzes anomalies in the participant's oral output, like the errors pattern and hesitations. The role of the face analysis service is to process the learner's online video while he/she is reading controlling head pose, eye gaze and the distance from the monitor, useful elements for examining attentional processes and frustration. A further tool to complete the profile of the user consists of a special section used by the teacher who can keep notes and store information about the individual reader. Because of all these features, the software is able to construct an individual profile of the users and of his/her errors that it is the base to prepare and to present personalized texts and exercises. Furthermore, the software is able to provide interface output based on the user profile, like predictive highlights of difficult words, changes in the velocity of reading, cues to pronunciations, changes in the font of the texts or specific letters, segmentation of paragraphs, sentences and words, integration of images. The great potential of this tool is the monitoring of the user's improvements (Athanasaki et al., 2007; Schmidt. Schneider, 2007; Tzouveli et al., 2008).

Writing. Many dyslexic people often have problem in writing and are thus also dysgraphic. Some studies demonstrated that reading problems are often overcome, but writing problems are persistent in spelling and written composition (Beringer et al., 2008). Compensative technologies for writing can be divided in two main categories: word prediction and speech-to-text software.

Word prediction software is design to suggest possible desired words during their digitation. This is achievable thanks to predictive algorithms that compute a sort of cloze-probability, i.e. the most likely words that starts with the typed letters, but also taking into account grammatical constraints and, in more sophisticated software, contexts based on the sematic distance between already typed words. Dyslexic people can take advantage from this type of technology by virtue of the rapidity in selecting words and the increasing vocabulary choices. It was demonstrated that such systems can improve spelling accuracy, fluency and the quality of written texts (Peterson-Karlan, 2011). However, this system can be used only when the list of alternative words for each position is not too long, i.e. between 3 to 5, given the perceptual and memory difficulties of the dyslexics (Andersson. Draffan, 2005). Furthermore, word decoding abilities and phonological awareness is required to provide the first letter and to choose possible words.

We can cite **FASTY** as an example of word prediction software that may benefit poor readers. This system has a dedicated interface where words are suggested. FASTY is able to predict the words thanks

to grammatical position, morphology cues and the semantic analysis of the text typed up to that point. The system exploits the word frequency of the specific language and suggests a list of words based on the score they obtain. Writing the chosen alternative into the text is possible thanks to a standard keyboard, an on-screen keyboard, or by scanning and selecting it among the suggested list is done by pressing a designed key. Furthermore, it is possible to listen to the suggested words of the list thanks to an integrated text-to-speech software, useful for people who has reading difficulties. Languages supported are Dutch, French, Swedish, German, Italian and Rumanian (Matiasek et al., 2002; Beck et al., 2004).

The second type of product is the speech-to-text software that allows dyslexic children to overcome difficulties in writing. Speech-to-text systems convert spoken language into writing. More sophisticated programs are able to create a phonetic model of the user that is compared to the vocabulary, becoming more and more accurate.

Advantages for dyslexics derived from the necessity to read the text and to monitor the composition while it is produced. In this way, the user is forced to read the word just pronounced taking advantage of the matching between oral and written presentation that can be useful to train phoneme-grapheme correspondence (Raskind. Higgins, 1999). Furthermore, word recognition and comprehension skills improve (Higgins. Raskind, 2000) as did the complexity of compositions (Graham, 1999).

The ability to use speech-to-text software improves with practice, but at the beginning it can be frustrating to learn not only how to use the software but also how to compose good written texts by speaking. Oral conversation is really different from composing well-structured texts, which tend to avoid repetitions and require the right punctuation (Andersson. Draffan, 2005).

An example of this kind of software is **Dragon Naturally Speaking**, a fine-graded system that comprises three functions: dictations - the speech-to-text system -, text-to-speech to listen to documents, and a sophisticated control input system thanks to which the user can give vocal commands to the system. The voice recognition component provides better outputs with training, during which the system considers different voices features, like inflections and tonality. It was found that texts of students with learning disabilities produced with Dragon Naturally Speaking were better than their handwritten compositions and comparable to texts produced by peers (MacArthur. Cavalier, 2004).

2.2 Advantages of Assistive Technology for dyslexia

In this section we consider why technologies can favor dyslexics, given their functional deficit but also their skills.

In our opinion five main factor can be cited as powerful features of technological tools that can support learning for dyslexics: (a) multisensoriality, (b) the rapidity of information processing and large memory size, (c) motivation and curiosity, (d) autonomy, (e)

inclusivity.

Multisensoriality. Dyslexics problems in sequential processing favor learning through different sensory channels which a) often offer more opportunity for parallel processing and b) provide supplementary information that can integrate faulty processing. The introduction of multimedia computerized applications in everyday activities allows dyslexics to approach information in alternative ways, benefiting from the simultaneous availability of texts, sounds, video clips, animated and static images offered by the tech devices. Furthermore, the uncertain origins of the deficit and the inter-individual differences in performance of dyslexic's lead experts to postulate the necessity of multisensorial bases of teaching methods where all perceptive modalities (vision, hearing and touch) are integrated in promoting language skills when they are not automatic (Dimitriadi, 2001).

Rapidity of information processing and large memory size. Computers are devised for applying rules automatically and systematically and they can memorize huge quantity of data. Their automaticity can assist dyslexics whose reading and writing processes are slow, non-automatic and effortful.

An explanatory example consists in how writing problems can be overcoming. In particular, dyslexics can produce illegible text, full of errors and, given the reading difficulties, they do not often read what they write. Computers provide aesthetic features to texts thanks to typing, or orthographic accuracy, thanks to orthographic editors, helping the writer to focalize the attention to errors. Furthermore, texts can be reproduced, reworked, easily available, memorized and shared. This allows dyslexics to inspect, re-use and compare texts (Peroni et al., 2010).

Motivation and curiosity improvement. Dyslexic children may suffer of psychological problems due to their difficulties in the school environment. Emergent emotional problems derived from scholastic failures can already be observed during the first year of school. Some causes are the inability to encounter parents' and teachers' expectations, the anxiety that comes from the confusion experimented during class lessons, and from the comparison with the success of other children. A dyslexic child can feel his/herself under pressure every time he/she has to perform a task; his/her frustration produces fears and this can cause passivity during class activities with negative effects on self-image and self-esteem (Ryan, 2004).

Informatics tools, in particular compensative technologies allow to follow class lesson in an alternative manner: for example, hearing a text or using a pc for writing. In this case technology, as an assistive tool, is not a means that facilitates school experience preventing linguistic skills development, but it is a means that helps in training these skills and compensate functional weaknesses due to the deficit. By adopting tools that help to show their competences, to learn new contents and to participate in the classroom, children can overcome the sense of frustration, and can improve motivation for learning and

epistemic curiosity.

Furthermore, rehabilitation program thorough ICT can be devise taking into account the playful dimension of learning. Most of the rehabilitative technologies devised for training of deficit linguistic skills are designed as videogames. Playful aspect motivates the child, and he/she can learn with fun and can learn autonomously comparing his/her scores and improvements (Peroni et. al, 2010). To take advantage of technologies as a play tool student need to be taught how to use and integrate such technologies into the educational context in order to avoid their potential distraction (Dell et al., 2012). The support of teachers is fundamental in this enterprise.

Autonomy. One of the main purposes of Assistive Technologies is to increase autonomy of the user. AT is helpful in overcoming barriers and offers the possibility to learn independently. Therefore, technology allows a greater freedom in organizing one's own learning in an autonomous manner making use of metacognitive strategies, self-motivation and taking into account individual and social behaviors (Hasselbring. Bausch, 2006). To guarantee autonomy, it is necessary that children are enabled to work in educational settings not only alone, when needed, but also with others as peers, specialists and parents.

Inclusivity. With this term we refer to a particular learning approach that consider the classroom as a micro-society, where all the actors are involved in the improvement of individual and collective knowledge, in social participation and in discrimination rejection. In an inclusive classroom special needs are accepted and valued (Polat. Kisanji, 2009). Assistive technologies might be used in the class as a support to dyslexic children in didactic contents during frontal lesson. However, when working groups are required to facilitate learning it is indispensable to stimulate the peer collaboration in an environment in which dyslexic students can fully participate. With the support of technologies students can be motivated in learning but also in socializing and sharing knowledge (Chen et al., 2010). To avoid the exclusion of a dyslexic children that use an AT in the classroom and to promote inclusion and social behavior, technologies can be introduce during moment of sharing. In detail, working together in front of a pc, or another multimedia tools, as digital blackboards, can promote motivation, fun, but also can give the opportunity to share knowledge in a dynamic manner, not only through reading and writing, but also through multimedia presentation, oral presentation thanks to which dyslexic children can take advantage from the help of the other peers but can also share their knowledge thanks to other sensory channels involved and their technological experience.

3. Developing Countries: problems and opportunities for dyslexia

3.1 Problems in diagnosis and treatments of dyslexia

Diagnosis of dyslexia requires the comparison between children suspected to be dyslexic and two different control groups of children: children with the same age and school grade and children with the

same level of reading and writing abilities. This double comparison allows for controlling a number of variables, including the effects of school level. Dyslexic children present reading and writing deficits, but a level comparable to age-related children for others cognitive abilities. Thus, the comparison with peers should yield no differences in tasks that do not involve reading and writing. Therefore, it is important to track the educational history of an individual in order to define the nature of the observed difficulties. For example, many children, considered at risk of dyslexia but who are actually false positives, come from disadvantage families, in which the quality of infant education and the pre-scholastic experience are poor; or they come from a poor school environment in which basic literacy skills are not well trained (Lyon et al., 2003). In order to diagnose dyslexia, cultural factors that can influence literacy skills acquisition should also be taken into account, especially in situation in which underachievement might hide dyslexia or might induce a false diagnosis (Nag. Snowling, 2012; Naeem et al., 2104).

In many countries standardized tests and reference points for the diagnosis of dyslexia are available and routinely employed; however, in many other countries a standard for a diagnostic test for dyslexia does not exist. This makes the detection of dyslexia very difficult, and one of the index associated with dyslexia, i.e. the failure in school achievement, might not be due to dyslexia, but to a poor educational environment, lack of good teaching strategies, difficulties in attending school, etc. In a recent paper, Naeem et al. (2014) pointed out that to identify specific learning disabilities, such as dyslexia, in Pakistani school is a "myth" because of the high rate of illiteracy among children. The lack of investment in the school system in the Country causes low quality of teaching, due to unskilled teachers and the absence of up-to-date pedagogical programs. Dyslexia treatment and identification is a problematic issue in such countries, where economic and social factors render the educational system un-effective.

In what follows we discuss two main categories of problems that may prevent identification and/or treatment of dyslexia: poor educational setting and linguistic context.

Data about the worldwide rate of literacy per country indicate that, of the 182 countries listed in the 2011 United Nations Development Programme (UNDP) Report, 102 have a literacy rate of 90% or above, 12 are below 50%, and the remaining 68 are in between. This is a clear indicator of an inadequate schooling level and of an unequal distribution of educational resources. Furthermore, teacher quality and availability are a common issue in developing countries (see i.e Job. Cerni, 2012). Teachers often have weak incentives and little supervision, and a substantial level of absenteeism is registered. Moreover, the teachers' incentives are often function of exams score; for this reason, instruction is often based on rote learning, copying from textbooks onto the blackboard, and having students copy from the blackboard. As Glewwe and Kremer (2005) claim, only 90 percent of primary school teachers and 69 percent of

secondary teachers are trained and the required training for these teachers is general lower than that of developed countries.

Regarding dyslexia, a key factor is that teachers have to be trained to target possible children with poor reading skills. In countries where public services are limited, education becomes a luxury item and this state of affairs may be coupled with bad pedagogical intervention, with the result of not only preventing children to become literate but also to limit, for children attending school, the detection of dyslexic symptoms and, thus, the possibility to diagnose dyslexia accurately and early on. For these reasons, some humanitarians' associations promote the diffusion of Dyslexia awareness. For example, Dyslexia International has assembled a global volunteer network composed by scholars, educators, governmental and non-governmental partners that are working to broadcast information, tools and trainings in dyslexia identification and intervention to educational figures (Dyslexia International, 2014).

Another crucial factor that make dyslexia identification a "myth" is multilingualism. In many developing countries several languages may coexist, with one or some of them having a privileged status while the other(s) being used in daily life interaction within groups of different status. Often the country official language may not coincide with the set of idioms spoken by the majority of the population that may not know the official language (Geldof, 2008). The different languages may act as a barrier between groups – yielding inequity and discrimination, and individuals may have the necessity to learn several languages in order to reach their life goals (see i.e. Cerni. Job, 2012). A great problem in these contexts consists in the fact that these official languages are the unique languages use in the schools and many children face enormous difficulties before starting to learn reading and writing. For a dyslexic child, this means a great risk of failure in achieving educational goals and in a delayed or an absent diagnosis.

3.2 AT as an opportunity

Both rehabilitative and compensative technologies can be useful tools in situations in which the educational environment is poor, not only because they can provide training and assistance for poor readers, but also, as we have seen in paragraph 2.3, because of their constitutional and social features that promote learning.

Technologies in general are promising tools in developing countries. As Job and Cerni (2012) pointed out, ICT has been widely used as an instrument for literacy acquisition for several reasons. It allows to reach individuals and groups that are far in space and time; it is long-lasting, multisensory, and flexible in terms of the information it can deliver; it may compensate for the shortage of teachers and educators, if appropriately used; it can capitalize on motivation and curiosity on the part of the children. ICT can assume the role of integrative and substitutive tool. On the one hand, it may be used as a helpful tool by teachers in the school setting; on the other hand, it may also be a tool where teachers and school are not present. Where educational environment is poor and not well prepared in identifying

children at risk of dyslexia, ICT can become a unique pedagogical method and may substitute the classical educational system tools, because it can reach large part of the population, including the disadvantaged. In this perspective, ICT can replace low-skilled teachers and assist education in areas that lack of teaching materials and rehabilitative programs.

Furthermore, the rapid diffusion and innovation of ICT, that lowers the cost of devices and makes them more durable and easier to use even for people who cannot read and write, seem to make these computerized devices more feasible to the context of developing countries, characterized by physical and socio-economic barriers. A recent incentive for developing situation is offered by mobile devices, today widely widespread thanks to the rapid evolution of computing and price lowering. The market, and the correlate request by users, is providing more and more complex and compact devices that have the features of being personalized, user centered, networked, ubiquitous, and durable (Motiwalla, 2007; Cerni. Job, 2012). Therefore, technological diffusion is a promising solution to face literacy problems but also to provide more targeted pedagogical trainings and specific assistance for dyslexia. As we have seen, AT for dyslexia are often able to monitor and report results of users, to provide automatic evaluation and appropriate exercise for the reading level of the user. In this way, these technologies can be useful to a teacher, that can take advantage of a computerized tool devised to monitor reading level and improvement, to draw attention to problematic situations and to suggest how to proceed in the educational path by monitoring achievements.

Distance education, multi-channel learning, the active role of the learner in an inclusive class, his/her autonomy in life are goals that converge to shape an adequate learning environment. Therefore, pedagogical aspects and the technological aspects should be considered jointly, in order to favor productive learning environments and to provide effective teaching tools. In our opinion, an automatic, user-centered and well-programmed pedagogical but also diagnostic intervention, implemented by means of AT could support poor educational settings and ensure equality between readers. Furthermore, a fine-graded intervention with AT should consider not only the educational system, specific of each country, but also the cultural environment and the language used with its specific peculiarities in diagnosis and treatment for dyslexia. These interventions should be the target of future research.

In conclusion, the role Assistive Technologies consist in allowing to children with disabilities the access to contents and the overcoming of specific difficulties. As a basic human right, AT insertion in developing situation, where educational settings are poor, is highly recommended as a world goal.

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