Design of Customizing Applications to Support Dyslexic Children in Reading

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ABSTRACT
This paper presents a preliminary study aiming to define a list of guidelines for designing effective software tools to support dyslexic children while reading an e-text. We start our work with a literature review, which main result is that, to our knowledge, such guidelines do not exist. After introducing the main difficulties met by dyslexic children in reading, we highlight two categories of actions that should be inserted in an effective tool for dyslexics: personalized text visualization and supported reading. Then, we describe an application we developed as a design example. Finally, we conclude with some preliminary considerations about how to evaluate the designed applications.

Categories and Subject Descriptors
H.5.1 **[Information Interfaces and Presentation]**: Multimedia Information Systems – *animations, artificial augmented and virtual realities, audio input/output, evaluation/methodology, hypertext navigation and maps, video (e.g., tape, disk, DVI).*

General Terms
Design, Experimentation.

Keywords
Dyslexia, Assistive Technology, Reading Tools, Personalization.

1. INTRODUCTION
People with dyslexia, estimated to be 5-10% of the European population [7], represent a relatively large group of the population.

Dyslexia is a severely invalidating learning disability related to reading. It does not imply low intelligence or poor educational potential but it strongly affects literacy acquisition. This disability is often characterized by difficulties with word recognition, decoding and spelling. Such difficulties negatively impact on reading comprehension and slow down vocabulary growth.

Although its causes are still widely debated, most of researches agree on considering reading as one of most efficient ways to overcome this disability [15]. However, the difficulties met during the reading, mainly characterized by poor reading fluency, poor reading out loud and several reading errors, discourage the dyslexics to practice it.

Even if dyslexia has neurological and often genetic origin, the difficulties connected to it can be mostly overcome with proper strategies [15]. From this prospective, assistive technology based on hardware and software applications can become a valuable and efficient support for dyslexics. Particularly important it would be having effective reading tools for *children* with dyslexia, to allow them to have a normal school life and avoid their unnecessary suffering and frustrations.

However, to our knowledge, guidelines for designing such applications do not exit.

Moreover, despite of a homogenous diagnostic categorization, dyslexics presents different difficulties and different disability levels. For this reason, customizing applications, tailored on the specific personal dyslexics' needs, would be definitely precious. Within web applications for dyslexic people, a good example is given by [5], presenting a customization toolbar to support the visualization of Web content according to preferences and needs of dyslexics.

In this paper, we first highlight the main difficulties met by people with dyslexia in reading. Then, we introduce how to design possible customizing software tools able to support dyslexic children in reading. In particular, we focus on the design of applications proposing personalized text visualization and supported reading, features that allow to overcome typical visualization and phonological problems in dyslexic children. An implemented application is presented as example. Finally, some considerations also concerning methodologies for evaluating this kind of applications are outlined.

2. DIFFICULTIES IN READING
The difficulties met during the reading, mainly characterized by poor reading fluency, poor reading out loud and several reading errors, discourage the dyslexics to practice it. Reduced reading experience impedes the growth of vocabulary and background knowledge, negatively impacting on the reading comprehension skills [10].

Among the reasons of difficulties in reading, there are visualization problems and limited phonological skills.

2.1 Visualization Problems
People with dyslexia are abnormally affected by crowding, a perceptual phenomenon with detrimental effects on letter recognition [1]. Since letter identification is fundamental for good visual word recognition and reading aloud, crowding strongly impacts not only on reading speed but also on reading errors.

However, letter recognition may be modulated by spacing between letters [1]. In particular, recent studies (e.g. [13],[17], [19]]) have demonstrated that a simple manipulation of the letter spacing, as well as specific fonts, can considerably reduce the crowding phenomenon and improve text reading performance of dyslexic children [18].

In addition to a distorted perception of the texts, dyslexics suffer a visual irritating glare from white pages. Therefore, it is preferable for them to not use white background or, more generally, to reduce the contrast between written text and background [2].

2.2 Limited Phonological Skills

Students with poor phonological awareness skills struggle with reading and spelling [16].

Phonological processing/awareness is meant as the processing of acoustic signals with linguistic content. It refers to knowledge of the sound units (phonemes) used in a language, including the abilities to hear and produce separate phonemes.

Phonological processing is based on three main components: a) phonological awareness; b) naming speed, and c) phonological working memory.

A child must be able to isolate and blend sounds into word parts and words to learn to read and spell. Without strong skills in phonemic awareness a child cannot begin to connect the sounds of language to letters or letter combinations. For many dyslexics, this is a very challenging task, as confirmed by their great difficulties in decoding and encoding.

Many studies show that dyslexic children have a deficit in phonological awareness (more specifically in phonemic awareness) [3]. Such deficit causes difficulties with accurate and/or fluent word recognition, spelling and decoding abilities. This deficit is independent of nonverbal IQ and may persist into adulthood. Early specific interventions tailored to individual phonological processing deficits may prevent later dyslexia

3. DESIGN OF TECHNOLOGY

If specifically designed for dyslexics and tailored on their specific needs, Assistive Technology based on hardware and software applications may become a valuable and efficient tool to compensate and support learning disabilities.

This is specifically true if dyslexics start to use them as soon as possible, when they are young [9]. We consider here compensatory systems for dyslexics, i.e. those tools that do not cure the specific learning disability but compensate rather remedy. They allow a person with a learning disability to demonstrate and apply her/his intelligence and knowledge.

After a literature review ([3], [5], [13], [19]), we identified two main functionalities that should be implemented in an effective compensatory tool for dyslexic children: personalization of text visualization and supported reading. In the following, we will describe these functions in detail.

However, due to the fast evolution of Information Technology (IT), other more sophisticated solutions will be available in the near future. For example, considering the fact that dyslexic children are easily distracted from reading activities, a reader connected to an automated attention detection module could be useful to understand when a child is losing her/his attention and then propose to her/him suitable stimuli to recapture her/his attention on the text.

3.1 Personalized Text Visualization

Text visualization can be changed in order to make easier the text reading, according to specific user needs (see also Section 2.1). Several guidelines, well elaborated and summarized in [4], help in designing applications tailored on dyslexics' needs. De Santana et al. group these guidelines in 9 elements, according to the traditional User Interface (UI) design.

Specific recommendations about text presentation (text size, alignment, animation spacing), colors (text and background), and page layout, are provided. Furthermore, a specific item about "End User Customization" is explicitly reported. According to this, an application should be designed so that its users are easily able to configure color scheme (background color, text color, and printing color), text size and font type.

3.2 Supported Reading

Dyslexics also have typically memory and attention problems [11] and phonological difficulties (see Section 2.2). These problems entail inaccurate reading with spelling errors and omission of words, high degree of distractibility and frequent loss of the place when reading. Audio files, pre-recorded or automatically generated by vocal synthesis, combined with word highlighting, significantly help in keeping attention and facilitate text reading and comprehension [11].

The text reading may be facilitated by hearing a) audio files pre-recorded containing the voice of a person reading the specific text; this function is called *audio reading*, or b) a voice generated on any text by text-to-speech synthesis. In both cases, the written word read is highlighted, so to help the reader to better follow the voice with attention while silently reading.

In addition, reading aloud may be made more effective by a checker based on speech recognition that corrects the reader in case of reading errors.

The text reading may also be facilitated by the use of a reading-aloud checker, a function based on automated speech recognition technology. With this checker, the child may read aloud the text; when he/she wrongly utters a word, the checker alerts the child and proposes the correct audio word.

3.3 An Example of Application

Following the guidelines summarized in [4], we designed and developed an application aiming to support children with dyslexia while reading an e-text. In the first version of our tool, we only focused on the aspects concerning the personalization of the text visualization. Other functionalities will be implemented and tested in the near future. The system has been designed according to the user-centered design approach, collaborating with experts of AID (Italian Dyslexia Association).

Figure 1. The customizing toolbar developed

Similarly to [5], our application is a web tool. The reader may personalize the visualization of the text using the buttons inserted in the toolbar on the top of the page (see Figure 1). The text customizing bar has been specifically designed thinking on the fact that children need tools that are simple, intuitive and easy to access and use. For these reasons, we used standardized icons and a simplified layout.

The personalization is accomplished by four main actions: change of a) font size (from 10 pt to 32pt), b) font and background color, c) character spacing, and d) word spacing. Figure 2 represents two screen shots of the application: Figure 2-a depicts a text with standard font parameters (font-type: verdana; font-syze:12pt; line-spacing:1.0px; letter-spacing: 2.7pt), whereas Figure 2-b depicts the same text with increased font-size and letter-spacing, according to [4].

In order to assess the impact of using specific values for font size and character-word spacing on the comprehension of a story by dyslexic children, a preliminary study was conducted.

Our application was used to set up two different textual visualization of an e-story.

Nine 10-year old children, attending the fifth grade of an Italian primary school, were involved. Among these, six children were dyslexic and the other three were normal readers.

Participants worked singularly. They were asked to read a short story extracted from a school book, 900 word length. The experimenter chose the colors of font (blue) and background (cream). The three normal readers and three dyslexic children read the text visualized with standard values for font-size and character-word spacing (font-size equal to 14pt and character-spacing equal to 2.7pt) (see Figure 2a), whereas the other three dyslexic children read the text visualized with font size equal to 18pt and character-spacing equal to 5.2 pt (see Figure 2b). Children read once the story without time limit. After reading the story, they had to answer to nine comprehension questions.

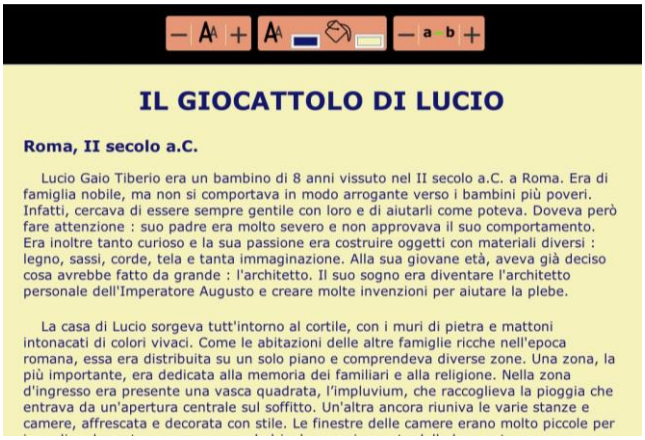
The study results confirmed what literature says about effectiveness of text visualization on dyslexic children, even if the study involved only a few users. Indeed, the normal readers spent averagely 8 minutes reading the story and gave 6 correct answers, the dyslexic children reading the text with the same visualization as the normal readers spent averagely 17 minutes in reading and gave 4 correct answers, whereas the dyslexic children reading the story visualized with modified font size and character-word spacing spent averagely 11 minutes in reading and gave 5 correct answers.

4. CONCLUSIONS

In this paper we presented a preliminary study aiming to define a list of guidelines for designing effective software tools to support children with dyslexia while reading an e-text.

After having described the main difficulties met by dyslexic children in reading, we focused on two main functionalities that should be included in an effective tool for dyslexics: personalized text visualization and supported reading. Then, we presented an application we developed as a design example. A preliminary study, conducted on 9 children, has confirmed the positive impact of proper changes of text visualization on the text comprehension. However, some doubts persist: is it correct to assess reading and comprehension skills of dyslexics by means of comprehension tests in turn based on reading and comprehension skills of the questions? Especially with children, the risk of collecting not significant or incongruent measures (see for example [14]) is very high. Also in order to get more reliable results, would not it be more appropriate to use objective methods based on automatic measures (e.g. log files, eye tracking), direct observations or video analyses?

Since there are not specific evaluation methodologies of application for dyslexic children, one first step to find possible answers to our questions is to conduct an extensive study of the several methodologies commonly used.



(a)

(b)

Figure 2: Standard (a) and modified (b) textual visualization

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