Interactive e-Books to Support Reading Skills in Dyslexia

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ABSTRACT

Developmental dyslexia is the specific learning disability in reading that affects the ability to read written text. In the current paper we explore the potential offered by interactive e-book technologies for supporting reading in people with developmental dyslexia. An important aspect of interactive e-books, which cannot be easily achieved with traditional printed media, is the ease of customizing the text layout in a way that can potentially help those with reading difficulties. We discuss findings from empirical studies in psychology and accessibility that identify best practices for presenting electronic text for readers with dyslexia. Moreover, given the spreading availability of e-readers and the flexibility provided by e-books to present content in different ways, we discuss the opportunities of using interactive e-books for improving reading skills. We believe that interactive e-books can be used not only as a support for facilitating reading but also as a way to develop and enhance the learning abilities of dyslexic readers.

Categories and Subject Descriptors

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Design, Human Factors.

Keywords

Interactive e-Books; Dyslexia; Learning Disabilities; Reading Difficulties.

1. INTRODUCTION

Developmental dyslexia is a specific learning disorder characterized by difficulties in reading acquisition despite adequate intelligence, conventional education, motivation to learn and sociocultural opportunity [1]. Dyslexia is characterized by a distinctive cognitive profile with specific areas of strength and weakness. People with developmental dyslexia have a preference for thinking visually rather than verbally and distinctive perceptual

abilities, such as sharper peripheral vision [10]. However, dyslexic people face challenges in acquiring automaticity in reading. As a result, reading is slow and error prone, which may influence reading comprehension and learning from text, with negative effects on the person's education and self esteem.

Several theories have been proposed for explaining the cognitive profile that characterizes dyslexia and its reading impairment (for a review see [5]). The more prominent theories view the reading difficulties as a consequence of a specific phonological deficit (the *phonological theory*), a deficit in the visual processing of letters and words (the *magnocellular theory*) or a coordination dysfunction (the *cerebellar theory*). These theories are still widely debated, but it is well established that developmental dyslexia has a neurobiological basis with a genetic origin.

Since dyslexia is a developmental disorder [5], it is present at birth and its effects are lifelong. However, reading difficulties can be reduced with early intervention that integrates appropriate training and the support of technology [9]. This paper provides an overview of technological tools that facilitate reading for dyslexic users, with a specific focus on interactive e-books. Specifically, the main contribution is a review of the literature on the text formatting that should be adopted for facilitating the reading of digital material, and a discussion on how interactive e-books can be used in the intervention for reading difficulties.

2. FACILITATING READING THROUGH TECHNOLOGY

Readers with dyslexia found difficulties in reading text formatted in traditional ways. The main obstacles that a dyslexic reader might encounter while attempting to read text include:

Visual recognition difficulties, such as difficulties in recognizing and identifying words, letters and numbers. Word identification is also slowed by the effect of visual crowding, a perceptual phenomenon that refers to the interference of flanking letters on the recognition of target letters [20 , 18].

Phonological and orthographical difficulties that manifest themselves as problems in associating written letters (grapheme) with their specific sounds (phonemes) and in relating the sounds of language to letters and words with a consequent latency in naming.

These obstacles have an impact on the reading performance, leading to:

- Slow and error-prone reading;
- Misspelled words and difficulties in identifying and remembering complex and new words;

- Poor reading comprehension;
- Fatigue after reading for a short time.

Moreover, the reading impairment may be accompanied by difficulties in writing, especially in spelling and handwriting.

However, several studies have demonstrated that specific training programs and supports, such as changes in the text presentation, can improve reading performances and content comprehension [9, 5]. In the last decades technology has become an essential tool for helping dyslexic readers. In fact, the development of strategies for coping with reading difficulties often relies on the use of technology: children with dyslexia are encouraged to use computers for studying, both at school and at home. As a result, many students with dyslexia use technology such as:

- Software programs that combine **OCR** (optical character recognition) and **text-to-speech** (speech synthesizer), allowing automatic reading;
- **Speech recognition** applications to translate spoken words into text, which support the process of typing and spelling;
- **Spell-checkers** and **spell-predictors** for aiding writing and manipulating text;
- Software for creating **concept** and **mind maps** to organize the information in a visual manner.

Many of these functions are already integrated in most popular operating systems (across different platforms, from desktops to tablets and mobiles) and are embedded in many applications available for the wide audience, such as the voice recognition technology in Apple's OS X and iOS, the optical character recognition provided by Google Drive and the spell-checker included in office software suits. These functions can be integrated in interactive e-books and in e-reader applications. In addition to this, interactive e-books can be used to support the activity of reading electronic content by manipulating the text formatting.

3. DYSLEXIA-FRIENDLY FORMATTING

Research based on a sample of non-dyslexic readers suggests that reading content using electronic media, such as e-book readers, is comparable in terms of reading performance and text comprehension to reading text presented in traditional paper [11]. Nevertheless, these results might differ when considering readers with dyslexia: presenting text through an electronic media can indeed provide a substantial support for this portion of the readers' population [17].

Empirical evidence from psychological research has demonstrated the effect that certain manipulations of the perceptual features of the text may have on speed, accuracy and reading comprehension in readers with dyslexia [13, 20, 18]. Among e-book applications, many functions have been proposed for formatting the text in customized ways. These functions include modification of the font, rearrangement of the page layout and manipulations of the dynamics of reading [16, 17].

Guidelines for designing dyslexic-friendly content can be found in the area of Web accessibility [4, 12]. The British Dyslexia Association (BDA) [2] has proposed a set of recommendations on how to present "dyslexia friendly" text, with suggestions for both digital and printed content. This list contains a considerable set of recommendations, and suggests good practices for making material visually accessible for readers with dyslexia. However, the list is not based on empirical evidence and does not include recent findings, such as the potential benefit of using short lines of text [18] and a bigger letter spacing [20]. BDA's guideline has

been compared with a set of specifications for the visually impaired users [6]. The comparison suggests that accessibility recommendations for minimizing visual discomfort and for facilitating the visual part of the reading process of web pages can benefit dyslexic, partially sighted and non-impaired users as well [6 , 12].

The following list (and Table 1) present a summary of recommendations obtained from [2, 4, 12] and combined with recent empirical research from psychology and education:

Typeface (i.e. font families)**:** Guidelines suggest the use of typefaces that facilitate visual distinction between similar characters: for example, having long ascenders and descenders or avoiding mirror images for b/d, p/q and u/n. Moreover, sans-serif typefaces should be preferred. For these reasons, accessible guidelines recommend typefaces such as Verdana, Arial or Helvetica. Some typefaces have been specifically designed for readers with dyslexia (such as the free typefaces Lexia Readable[1] and Open-Dyslexic[2]) but more empirical research is needed to assess the benefits of using special font families compared to common ones [15]. Moreover, a study suggested that using slightly harder-to-read fonts might improve reading comprehension of short pieces of text in non-dyslexic and dyslexic students [8]. However, it is not clear whether using slightly harder-to-read fonts has an effect on long-term outcomes.

Font size: It is recommended to use a relatively big font size, ranging from 12 and 16 pt. It has been proved that a larger font size enhances reading speed and accuracy of younger and dyslexic readers [14]. However, its relation with inter-letter and inter-line spacing should be considered [18].

Inter-letter and line spacing: It has been found that a bigger inter-letter spacing facilitates reading in children with dyslexia [20]. Increasing the letter space of 2.5 pt can indeed improve reading performances in terms of time and accuracy in dyslexic children. Furthermore, adding spacing between lines can contrast the crowding effect especially in weaker readers [18, 17]. A stronger effect is expected from the co-variation of line and inter-letter spacing.

Line length: Shorter lines ameliorate reading speed and comprehension of both digital and paper-based text by helping to guide attention [18]. Moreover, reading digital material on a small screen displaying 2.1 words per line, compared to traditional presentations on paper showing 12 words per line, improves reading speed and comprehension [17]. Major benefits have been observed for dyslexic readers with diminished visual attentive resources. It was hypothesized that short lines might generally improve reading speed and comprehension by having an effect on the oculomotor behavior, reducing the probability that crowded text in locations previously fixated can be perceived [18].

Contrast: Contrast sensitivity has been reported to differ between dyslexic and non-dyslexic readers. Specifically, it has been proposed that dyslexic readers might benefit from low-contrast text, but this hypothesis has received weak or no support form empirical studies in psychology [13]. However, guidelines suggest to use dark colored text on a light (not-white) background.

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[1] Lexia Readable: http://www.k-type.com/?p=520

[2] OpenDyslexic: http://opendyslexic.org/

Table 1. Summary of recommended formatting styles

Formatting	Recommendation	References
Typeface	Sans-serif typefaces. No agreement on the best typeface (Verdana, Arial or typefaces specifically designed for dyslexia)	[15, 8]
Font size	Relatively big fonts (size between 12 and 16 pt)	[14, 20]
Inter-letter and line spacing	Letter space of 2.5 pt	[20, 18, 17]
Line length	Short lines	[18, 17]
Background and text color (contrast)	Background with light colors and text in black or dark grey.	No clear empirical evidence on the benefits of these recommendations
Alignment	Right-aligned text should be preferred.	
Emphasizes	Use bold for emphasizing	

Alignment and emphasizes: Right aligned text should be preferred. Justified text might create large uneven spaces between words, making reading difficult. Italics and underlined words should be avoided; it is suggested to use instead bold for emphasizing. However, there is no strong empirical data in the literature to support these claims.

It is important to note that inter-subjective variability in setting up the optimal values for these parameters is high, and it is inherently difficult to provide defined guidelines for a general profile of users with dyslexia. It is thus recommended to use a customizable and flexible environment, where the user, or someone on his behalf such as the therapist, the teacher or the parent, can adjust the values and configure their desired text layout.

Moreover, the studies considered in our review are based on samples with different age ranges: from primary school children [20, 14, 8], to high school students [17, 18, 13] to adults [15]. It is thus difficult to claim whether modification on the formatting could best support preschoolers, young readers or adults with dyslexia. According to clinical guidelines, dyslexia should be diagnosed after children have reached the first or second grade but it might be the case that adapting the text presentation might also benefit preschoolers and early-learners.

The flexibility afforded by e-books and e-readers to modify text formats demonstrate the potential in using these technologies to support reading with dyslexia. A number of applications have been designed for this purpose, taking into account some of the parameters presented in our review. These are mainly e-reader applications (e.g. [16]) and tools for adapting the presentation of Web content (e.g. [12]). However, reformatting the page might address the accessibility shortcomings of traditional formatted text or of printed books, but not necessarily improve the users experience when reading. In the next paragraph, we outline the specific benefits that interactive e-books might integrate not only for making text more accessible but also for developing the learning skills of dyslexic readers.

4. INTERACTIVE E-BOOKS TO TRAIN READING SKILLS

As previously discussed, interactive e-books can make reading easier for those with dyslexia because they permit formatting changes of the written text. Notwithstanding, the modification alone cannot address all of the difficulties faced by dyslexic readers [18].

A promising line of research investigates how e-books and e-readers can support different methods of reading with respect to traditional paper-based books, providing solutions that better meet the cognitive style of readers with dyslexia [3]. For example, an e-book can be read on portable handheld devices that might have small screens. Recent studies have provided evidence that using small-screen devices, such as smartphones, might help people with dyslexia to read faster and more accurately. It has been found that reading written content on a 3.5-inch screen using a particular method of text presentation, so that the text spans only a few words per line, improves speed and accuracy in students with dyslexia. This reading method, which can be implemented with commercially available e-reader software[3], might limit the attention span and reduce the demands on visual attention and memory [18, 17]. Moreover, holding the e-reader in the hand has proven to positively influence reading performance in dyslexic readers with reduced attentional resources. Having the text placed in proximity to the hand might help to maintain the focus of attention on the text, preventing visual interferences and improving allocation of attention [18]. Yet, major benefits have been observed specifically for dyslexic students who struggle most with phoneme decoding or have limited attentional span.

In addition, interactive e-books are tools that can easily permit the authoring of the content and its adaptation at different levels (e.g. formatting, content, modality). These features make e-books potential tools for supporting the treatment of reading difficulties. For instance, within a reading skills training program a therapist can modify the text properties (e.g. formatting, text length, dynamic of text presentation) of the children's e-readers for adapting them to the characteristics of the training. The flexibility provided by e-books allows the therapist to adjust the parameters according to the progress achieved as the training program progresses. The therapist can also monitor the progress and adjust the text properties remotely using the Web.

Interactive e-books might also be designed to harness adults as teachers and play partners for children during reading activities. For example, e-books allow one to record one's voice while reading, allowing parents (or the child him/herself) to record the narration. This is good training for memorizing and practicing word pronunciation. Moreover, interactive e-books might integrate functionalities that permit the reader to listen and practice the recognition of basic units of speech (syllables and phonemes) within different words. This activity can improve children's phonemic awareness: the awareness of the sound structure of spoken language and one of the fundamental skills for reading. Computer applications are already available as exercises in the form of games for training the recognition of phonemes, but the integration of this function in interactive e-books seems a promising addition: it has been shown that daily practice in letter-sound association is effective in increasing phonological awareness, and that in turn might have a positive impact in reading

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[3] Such as the iPhone app GoodReader: www.goodiware.com

abilities [9]. It is also worth noting that supporting practices for students with dyslexia within an educational context can alleviate difficulties faced by all students, including early readers and students with learning difficulties. From a developmental point of view, dyslexia should in fact be considered to be at the lower end of a continuum of reading ability that also includes poor and normal reading abilities [19]. Thus, it is likely that beginner or poor readers might also benefit from resources designed to support learners with dyslexia.

Another interesting line of research is the use of interactive games as training tools for basic attentional skills that, in turn, might affect reading abilities. Recent studies have demonstrated that it is possible to enhance specific attentional skills in dyslexic children, such as visuo-spatial processing, using specific video games [7]. These findings open up opportunities for integrating interactive activities in the form of simple games in e-books, making the digital reading more engaging and beneficial at the same time.

Taken together, these studies show that there is a great potential in interactive e-books: they are potentially accessible to users who have reading difficulties and can be used as tool for developing and enhancing reading skills. In reaching this goal, it is important to ground the design of interactive e-books on evidence-based findings in which cognitive aspects characterized dyslexia and in which intervention are actually effective. This paper is a preliminary step in guiding the design of interactive e-books for readers with dyslexia defining those characteristics that may improve the quality, the ease and the enjoyment of reading in children - and potentially also in adults - with dyslexia.

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