The Influence of Visual Information During Reading in Children with Dyslexia

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Abstract
According to current understanding, digital texts can be made accessible to children with dyslexia by presenting them in a simplified layout, with suitable fonts, or by using audio synchronized with word highlighting. However, the latter has not been elucidated as regards its impact on ease of reading for children with dyslexia. To determine whether the type of text highlighting color or underlined area affects the ease of reading for children with dyslexia, this study examined reading eye movement. Four children with dyslexia (two boys and two girls) between seven and ten years of age participated in this study. The digital texts were created using different text highlighting colors and underlines. The digital texts were read using the Apple reader application iBooks on a 9.7-inch Apple iPad Air. The results showed that reading along was easier with audio synchronized with text highlighting rather than without. The eye movement responses of children with dyslexia were affected by the color and area of text highlighting. Thus, the methods of presenting visual information in reading might help children with dyslexia to read.

Keywords: dyslexia, visual information, accessibility, digital content, eye movement

Introduction

Dyslexia is the most common neurological-specific learning disability (Lyon, et al., 2003). Dyslexic readers suffer from a phonological defect characterized by difficulties in associating phonemes with the symbols that represent them in written graphemes. In Japan, 4.5% of children with dyslexia have a learning disability. Moreover, 2.4% of children are hard to read or write (Ministry of Education, Culture, Sports, Science and Technology, 2012). Children with dyslexia have been found to exhibit longer durations of fixations and more fixations in reading compared with normally developing children (Hutzler & Wimmer, 2004).

Reading disability prevents to get visual information from printed materials in the standard reading. E-books become to show personalized information for individual reading style of each person. It is realized by accessibility function on operating system. Accessibility function is including text/background color combinations, font size, and line spacing. E-books with accessibility function promote readability to dyslexia (Evett & Brown, 2005; McCarthy & Swierenga 2010), and accessibility function is key factor of facilitate reading in dyslexia on mobile devices (Schneps et al., 2010).

E-books are made easily access to multimedia information that is not reproduced by paper media, including sound, video, and 3D images. Combination of multimedia information is able to show how to pronounce of words and helping understand of words meaning (De Jong & Bus, 2003; Lewin, 2000). Furthermore, multimedia information is able to satisfying the reader's curiosity (Ikeshita-Yamazoe et al., 2012). These evidences suggest that reading with multimedia information helps children with dyslexia. On the other hand, readability parameter of each informations were not detected. Especially, word highlight method was not established. Digital Accessible Information System (DAISY) format (National Information Standards Organization, 2005) and EPUB3 (International Digital Publishing Forum, 2010) has word highlighting function. However, section of word highlight is differ and not based on scientific evidences.

In present study, authors tried to clarify relation between readability and section of word highlight. Readability was evaluated by frequency of fixations from eye movement.

Methods

Participants

Four Japanese children with dyslexia (two boys, two girls) aged between seven and ten years old participated in this study. Written informed consent and consent forms were obtained from the parents and children, respectively. This study was approved by Ritsumeikan University (Kinugasa-Jin-2014-27).

Apparatus

The Eye Tribe (The Eye Tribe ApS) was used for recording eye movements. Eye tracking rate was set at 30 Hz, precision of tracking range was within 0.5 degrees. Measurement data were recorded on a laptop computer. Digital texts were showed on Apple iPad Air (9.7 inch screen) with iBooks application as an E-book reader.

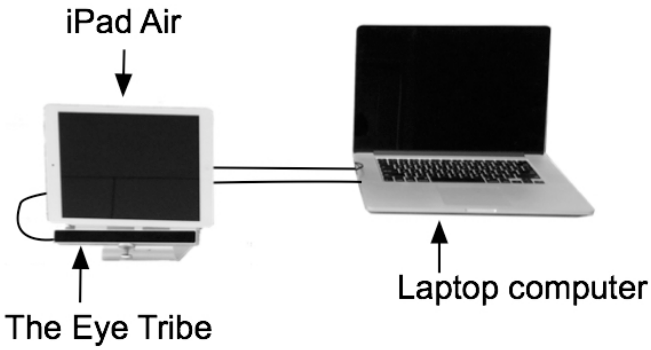

Figure 1. Experimental setup.

Stimuli

Sentences of digital contents were used from *Kabutomushi* ("Beetle"; Nankichi Niimi, 1943) which is storybook for children. Digital contents were prepared eight types from *Kabutomushi* in current study. One type of Digital content was used digital text without audio narration and word highlight. Another one type of Digital content was used digital text with audio narration and without word highlight. Other six types of digital contents were used audio narration with word highlight. Six types with word highlight were constructed from two highlight styles and three visual indicators combination. Two highlight styles were constructed from one word highlight style and one sentence highlight style. Each highlight styles have three visual indicators. Visual indicators were prepared underline highlight with black color (R:0, G:0, B:0), band highlight with yellow color (R:255, G:255, B:0) and band highlight with blue color (R:234, G:234, B:255). Sound was used common audio narration between seven types of digital contents with audio narration. Digital contents format was used EPUB 3.0 with media overlay function (DeMeglio & Weck, 2012). Media overlay of EPUB 3.0 is able to highlight words or sentences, and audio narration related highlight area. Audio narration was created by text-to-speech software (AITalk Plus, AI Inc.). Storybook was not read yet to participants before current study.

Procedure

Participants sat on a chair in front of iPad Air. Viewing distance was set 50cm from iPad Air screen. At first, participants were instructed about task. After instruction completed, participants were gazed black circle on white screen between 20 seconds for eye track calibration. After calibration done, participants were read eight digital contents continuous. After read completed, participants were rest at 60 seconds. One trial was constructed these read and rest. In current study, eight trials were executed. Order of digital contents reading was show at random between participants.

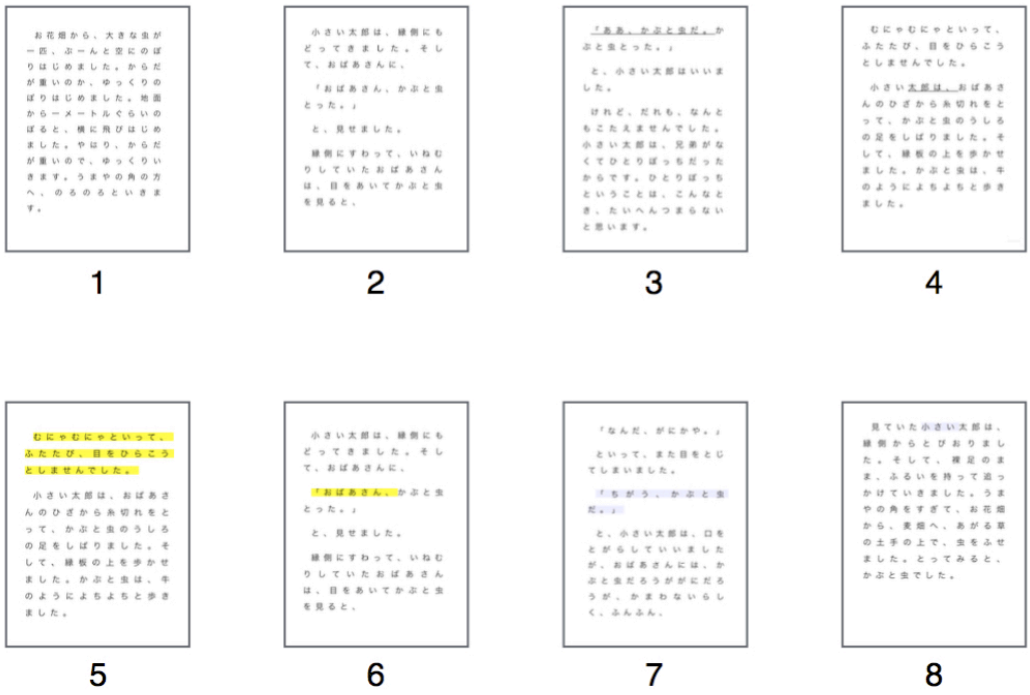

Figure 2. Eight types of digital contents.“1. Digital text without audio narration and word highlight,” “2. Digital text with audio narration and without word highlight,” “3. Underlining of a sentence,” “4. Underlining of a word,” “5. Highlighting of a sentence in yellow band,” “6. Highlighting of a word in yellow band,” “7. Highlighting of a sentence in blue band,” and “8. Highlighting of a word in blue band.” Order of task was at random between participants.

Results

Frequency of fixations was analysis from both eye movement data. Digital text without audio narration was higher frequency than seven other digital contents with audio narration (Friedman test, $p < 0.01$, results not shown in figure 3). One sentence highlight style with blue band indicator was significant shorter than among one word highlight style with blue band indicator ($p < 0.10$, n = 4, Wilcoxon signed rank test, z = -1.84, two-tailed) and one sentence highlights style with underline indicator ($p < 0.10$, n = 4, Wilcoxon signed rank test, z = -1.60, two-tailed). One sentence highlight style with yellow band indicator was significant shorter than one word highlight style with underline indicator ($p < 0.10$, n = 4, Wilcoxon signed rank test, z = -1.60, two-tailed).

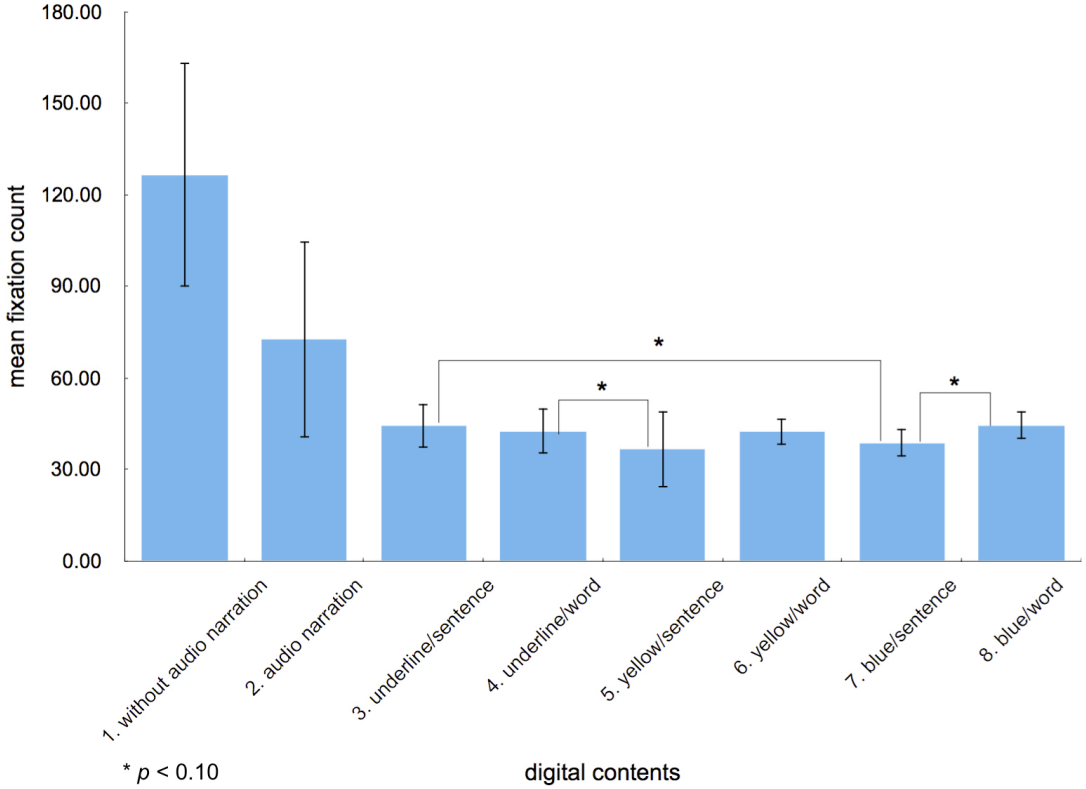

Figure 3. Mean fixation count in reading for children with dyslexia.

Discussion

In present study, one sentence highlight style is become facilitate reading, band indicator is more distinguish than underline indicator, and with audio narration is more appreciate than without audio narration. These results suggest that word highlight method is influence to readability from frequency of fixations, and audio narration was one of key factor of readability to children with dyslexia.
On the other hand, results suggest method of readability has multiple ways. This suggestion is able to think that readability is different from individuality. Thus, digital content like an E-book reader devices should equip customizing function for text reading. In future tasks, authors consider that clarify the relation between comprehension and digital text reading in children with dyslexia.

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