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Is visual content in textual search interfaces beneficial to dyslexic users?

Gerd Berget [a,*], Fiona Mulvey [b], Frode Eika Sandnes [c,d]

[a] Department of Archivistics, Library and Information Science, Faculty of Social Sciences, Oslo and Akershus University College of Applied Sciences, Postboks 4 St. Olavs plass, N-0130 Oslo, Norway
[b] Humanities Lab and Department of Psychology, Lund University, 221 00 Lund, Sweden
[c] Faculty of Technology, Westerdals Oslo School of Arts, Communication and Technology, Postboks 9215 Grønland, N-0134 Oslo, Norway
[d] Institute of Information Technology, Faculty of Technology, Art and Design, Oslo and Akershus University College of Applied Sciences, Postboks 4 St. Olavs plass, N-0130 Oslo, Norway

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ABSTRACT

Dyslexia is a learning disability characterised by problems with accurate or fluent word recognition, poor decoding, and poor spelling abilities. Although several studies have addressed dyslexia and Web accessibility, less is known about how dyslexia affects information search. This study investigated whether the inclusion of icons in search user interfaces enhances performance among dyslexics. A total of 21 dyslexics and 21 controls completed 52 search tasks in 4 conditions: icons only, words only, and both icons and words in a grid layout and a list layout, while eye movements were recorded. Dyslexics took significantly longer than controls to locate targets in tasks containing text, but not in the icon-only condition. Dyslexics had longer fixation durations than controls in both icon and text based search arrays, suggesting higher mental load associated with search tasks generally. The addition of words to icon arrays led to faster search times within controls, but not dyslexics. Dyslexics also exhibited more fixations on dual-modality tasks, and longer scanpaths than controls in list layout. Both groups were fastest searching the list layout, with icons and words listed in columns. Results are discussed in terms of the design of accessible search interfaces for dyslexic users, taking into account mental load of dual-modality information display, and the arrangement of search items. Empirical data is provided for the design of accessible search results interfaces for dyslexics.

1. Introduction

Dyslexia is related to impaired word recognition and decoding skills (American Psychiatric Association, 2013) and occurs in various forms and degrees (Snowling, 2000). Some dyslexics are fast but inaccurate readers, while others are slow and more accurate readers (van der Schoot et al., 2000). Dyslexia is usually discussed in educational contexts and in terms of teaching children how to read and write. However, dyslexics are also suggested to struggle with other activities, such as information retrieval (MacFarlane et al., 2010; Habib et al., 2012). Information search requires spelling skills in order to produce accurate and purposeful queries, and word recognition skills for exploring results and assessing documents for relevance. Either, or both aspects may present challenges for a dyslexic user.

Dyslexia occurs in 3–10% of the population (Snowling, 2000). Non-fluent and inaccurate reading is common (Shaywitz and Shaywitz, 2005) and reduced sequencing skills, concentration difficulties, impairments in word retrieval and a reduced short-term memory capacity are also reported (Snowling, 2001; Jeffries and Everatt, 2004; Mortimore and Crozier, 2006; Smith-Spark and Fisk, 2007; Hiscox et al., 2014). Dyslexia is persistent and chronic, and difficulties remain throughout life (Shaywitz and Shaywitz, 2005), effecting not only education but everyday activities such as Web navigation (Al-Wabil et al., 2007) and information search (MacFarlane et al., 2012).

Prevalence of dual diagnosis with dyslexia and other specific learning disabilities are not uncommon. Attention Deficit Hyperactivity Disorder (ADHD) or Attention Deficit Disorder (ADD), characterised by excessive activity, impulsivity and a short attention span, are reported in 18–20% of the dyslexic population (Germanò et al., 2010). The mathematical impairment dyscalculia is found in 4–7% of dyslexics (Landerl et al., 2009). Dysgraphia, a learning disability for writing, is also prevalent in the dyslexic population (Nicolson and Fawcett, 1990), as is dyspraxia – an impairment in the organisation of movement (Gibbs et al., 2007).

* Corresponding author.
E-mail addresses: gerd.berget@hioa.no (G. Berget), fiona.mulvey@humlab.lu.se (F. Mulvey), frode-eika.sandnes@hioa.no (F.E. Sandnes).

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1.1. Accessible search interfaces

The design of accessible search results has been discussed in a general user context. Some features have been reported to work well, such as colour highlighting query terms, and sorting or categorising results according to attributes such as date, author, or category labels (Hearst et al., 2002). Other studies have addressed certain types of search, for example, faceted search (Fagan, 2010) or personalised search (Sontag et al., 2012). However, according to Hepworth (2007) and MacFarlane et al. (2010), cognitive variations such as dyslexia in the user population are usually not addressed in research on information search behaviour.

Several studies have investigated Web accessibility and dyslexia in terms of ameliorating factors. Evett and Brown (2005) investigated how to produce clear and more readable text for visually impaired and dyslexic users. Font types and sizes have also been investigated. Rello and Baeza-Yates (2013) concluded that font types affect reading performance, and that italics should be avoided. It has also been suggested that dyslexics prefer font types without serifs (Evett and Brown, 2005).

Information layout is also discussed in the research literature. Zorzi et al. (2012) reported that increasing letter-spacing improved reading performance among Italian and French dyslexic children. Rello et al. (2013b) concluded that line spacing had no significant effect on reading performance, but font size had a significant effect. However, few studies have focused on search user interface design.

Al-Wabil et al. (2007) interviewed 10 dyslexics to investigate how dyslexia affects Web navigation. They found that dyslexics experienced significant navigational barriers online, and did not find internal search useful. Such barriers seem to effect online information production, too. Baeza-Yates and Rello (2011) used typical dyslexia-related writing errors to estimate the amount of texts written by dyslexics on the Web. They concluded that dyslexics were underrepresented as content producers, and that the implementation of natural language processing tools could improve Web accessibility.

Universal design has been much discussed in the context of the Web, and attempts have been made to develop guidelines which adequately accommodate user diversity. The most commonly applied guidelines today are the Web Content Accessibility Guidelines, or WCAG, developed by the World Wide Web Consortium (W3C, 2008). WCAG has become the de facto standard applied by developers, designers and legislators. However, it is difficult to design guidelines which accommodate all users. These difficulties are addressed by W3C in their introduction to WCAG (W3C, 2008), where they claim that the guidelines may not meet the needs of users with specific cognitive, language, or learning issues. Richards and Hanson (2004) and Rømen and Svanæs (2012) also found that Web pages that are complying with WCAG may not offer sufficient accessibility to all user groups.

WCAG does address issues such as ease of navigation and the importance of clear and understandable text, which applies to dyslexic users. However, since WCAG does not seem to adequately accommodate the needs of users with cognitive impairments, alternative guidelines directed particularly at dyslexic users have been suggested, for instance The British Dyslexia Association (n.d.) and Zarach (2002).

Friedman and Bryen (2007) reviewed 20 sets of guidelines directed at people with cognitive impairments, where three of these specifically addressed dyslexia. They found that the most frequently cited guideline for accommodating dyslexic users related to the use of pictures, icons and symbols in addition to text. This was mentioned in 75% of the literature reviewed. However, this recommendation is not included in WCAG (W3C, 2008). De Santana et al. (2012) reviewed guidelines concerning accessible Web pages for dyslexic users and categorised these according to topic. One guideline, referring to images and charts, states that textual information should be complemented with images and pictures and includes discussion of icons. The justification given for this guideline is that dyslexics tend to place more emphasis on images than words.

The advantage of visual content for dyslexic users is supported by Houts et al. (2006), who found that pictures could accommodate users with reading impairment. However, others have concluded that pictures may distract attention away from the text and thereby negatively affect reading comprehension. For instance, Beacham and Alty (2006) found that material containing text-only is most beneficial to dyslexic readers. Similarly, Brante et al. (2013) found that integrated pictures in learning materials did not help dyslexic students to better understand the content. However, Williams and Hennig (2015a) reported that users with learning disabilities *preferred* designs with large text and images, although these conditions did not facilitate the fastest search times.

1.2. Visual search and eye movement measures

Humans have high acuity, colour vision only in central vision, so that an area extending about 1.5° (the *fovea*) is available for detailed work such as reading or small object recognition, see for example Fulton (2000). Only 3–4 letters are thus visible in detail at any time during reading. However, parafoveal vision, extending out to about 5° from central vision, has higher acuity than the peripheral vision, and a parafoveal preview benefit is commonly reported in reading research (see e.g. Pollatsek, 2015 for a comprehensive review). This means that visual information is only perceived in high detail at the centre of vision at any one time, and details of any sort will be increasingly more difficult to recognise with distance from central vision.

Information retrieval is an activity which involves visual search, especially during results assessment. Eye movements have been widely used to investigate cognitive processes during visual search (for review, see e.g. Rayner, 2009). Most search tasks involve multiple fixations (Findlay, 2004). When the human eye is directed towards visual information, selected content is aligned to the central 2° of the retina; the fovea (Wright and Ward, 2008). The fovea provides the most detailed visual input, while visual acuity and colour information declines in the remaining $\approx 170^\circ \times 150^\circ$ peripheral vision. Consequently, to process objects in detail, eye movements are necessary frequently and quickly.

Eye tracking has been applied in several studies related to visual search and dyslexia, and is a valuable method for studying cognitive processes during reading and attention generally (Rayner, 2009). Rello et al. (2013a) used eye tracking to investigate cognitive load associated with different forms of number representation, and how different conditions affected understandability and readability for dyslexics. They found that numbers presented as digits were more readable than digits presented as words, and that percentages were faster to read than fractions. Kim et al. (2014) applied eye tracking to investigate how dyslexics comprehend graphs. They analysed reaction times and gaze durations, and found that dyslexics were slower than controls in graph comprehension.

Both fixations (stops the eye makes in order to process information) and saccades (movements the eye makes to select a new area for high acuity inspection) have been related to search performance, and it has been suggested that fixation durations may reflect cognitive load or task difficulty across a range of cognitive activities, including visual search. Rayner (2009) reported that fixation durations in visual search may vary from 180 to 275 ms, depending on the difficulty and density of the array.