The Effect of Dyslexia on Searching Visual and Textual Content: Are Icons Really Useful?

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Abstract. Little is known about how dyslexia affects online information seeking. This study addresses the search performance of 21 users with dyslexia and 21 controls in textual versus visual displays. The aim was to investigate whether visual content enhance search performance. Participants were presented with 24 icons and 24 words and asked to locate a target item. Eye-tracking data revealed no differences in performance in visual or textual content in the dyslexia group. There were no significant differences between the user groups on visual tasks. However, users with dyslexia performed significantly slower on textual tasks than controls, mainly due to longer fixation durations. Users in the control group took much less time solving textual tasks than visual tasks. The results indicate that there may be no advantages in replacing textual content with icons for users with dyslexia. However, replacing text with icons may be counterproductive for users without dyslexia.

Keywords: Dyslexia · Information search · Icons · Eye-tracking

1 Introduction

Dyslexia is a reading and writing impairment, which affects the abilities to recognize and comprehend written words [1]. This cognitive impairment is found in at least 3–10 % of any population [2], and it often entails a reduced short-term memory capacity, concentration difficulties, reduced sequencing skills and impairments in word retrieval [3–7].

Although dyslexia is most often discussed in relation to educational settings, users with this impairment may experience difficulties in other areas, such as online information searching [8]. For instance, browsing result lists may be a challenge due to the large amounts of textual content which needs to be assessed. Consequently, slow reading speeds and decoding errors, which are common among users with dyslexia [1], may affect the information search negatively.

The inclusion of visual content in result lists may reduce the workload associated with reading large amounts of text and thus enhance the search process for users with reading impairments. However, dyslexia is often associated with visual perceptual

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deficits [9], and several studies have addressed the visual search skills among users with dyslexia. Most of this research follow the traditional visual search paradigm, where the user is presented with an odd target item, and then asked to decide whether the item is present or not in a display with several distractor items [10]. Performance measurements are typically reaction times and error rates.

Several experiments with standard visual search tasks have concluded that users with dyslexia are impaired in visual search tasks [10, 11]. This impairment is found both in children [12] and adults [13]. Vidyasagar & Pammer [14] found a set-size effect on feature tasks, where users with dyslexia performed significantly poorer than the controls in tasks with a large number of distractors.

Some studies have suggested that only certain users with dyslexia are impaired in visual search, or that the deficit is related only to some types of tasks. Iles, Walsh and Richardson [15] suggested that impairments in visual search tasks are related to specific characteristics in dyslexia. Moreover, they found that participants with dyslexia with a motion coherence deficit were impaired in serial search tasks, while the users with normal motion coherence were not impaired in any of the visual tasks in their study. Prado, Dubois & Valdois [9] concluded that although users with dyslexia had atypical eye movements during reading, such eye movements were not found in visual search tasks in letter-based stimuli. Consequently, atypical eye movements had no impact on the performance on visual search tasks.

This article presents the findings from a study where 21 students with dyslexia and 21 students in a matched control group conducted 12 search tasks each in textual and visual content. The aim was to investigate whether visual content facilitated the search process. The hypotheses were that users with dyslexia would perform better when searching for icons than for words, and that the control group would perform better in the textual tasks than the users with dyslexia.

2 Method

2.1 Participants

The participants comprised 42 volunteering students, 21 diagnosed with dyslexia and 21 controls. Three people were diagnosed with ADHD or ADD (two users in the dyslexia group, one in the control group). Comorbidity of dyslexia and AHDH is quite common [16].

A Norwegian word chain test [17] confirmed group affiliation. Low scores are indicative of dyslexia where adults who score below 43 are recommended further diagnostic tests. The students with dyslexia scored significantly lower ($M = 39.7$, $SD = 10.2$) than the control group ($M = 60.3$, $SD = 9.7$), $t(40) = 6.7$, $p < .001$.

The control group was matched with the dyslexia group according to gender, age, field of study and year of study. Both groups were evenly distributed according to gender, with 57.1 % females and 42.9 % males. The mean values of age were 24.0 years for the dyslexia group and 23.4 for the controls. The participants followed bachelor programmes or master programmes in nursing, engineering, educational training, social sciences and humanities. The mean year of study was 2.3 for both groups (bachelor students counted as year 1–3, master students as 4–5).

Visual acuity tests using Landolt C charts ensured that the participants had normal vision, since reduced visual acuity could affect the outcome of the experiment. All students were tested on 4 m for far sight and 40 cm for near sight, which is the European standard [18]. The students had at least an acuity of 0.6 on each eye separately and 0.8 with both eyes open on both tests, which is considered within the range of normal vision [19].

2.2 Procedure

Each participant completed 24 search tasks; 12 in visual content and 12 in textual content. In addition, the students were given one rehearsal trial for each stimulus type. The tasks were presented in sections of six of each type. If an icon or a word had been the target of a search task, it did not reappear in later tasks as distractors to ensure that the students with reduced short-term memory would not get confused regarding which target to search for. The consequence of using this research design was that all participants were presented with the tasks in the same order. All tasks were completed in one session, and the participants were not spoken to except if they asked a question to the experimenter. The participants commented on specific searches during debriefing where unusual behaviour was observed.

2.3 Apparatus

Eye movements were recorded with an SMI RED remote eye-tracker at 250 Hz. A chin rest was used to reduce the head-motion during the session. Stimuli files were created in Adobe Photoshop CS4. The experiment was created and run in the visual presentation software SMI Experiment Center 3.2.11. A 21' flat screen Dell LED monitor was used to display the stimuli with the screen resolution set to 1680×1050 pixels. The behavioural and eye tracking software SMI BeGaze 3.2 and the statistical analysis software IBM SPSS Statistics 22 were used for data analysis.

2.4 Materials

For each trial, the participant was presented with three views: an instruction of search target, a fixation cross and the search task (see Fig. 1). The instructions were presented in pre-recorded sound files using speech synthesis. The verbal instructions prevented spelling of the textual targets to be revealed. The instruction was followed by a fixation cross, which appeared either in one of the corners or the middle of the screen in random order. The fixation cross was a trigger area of interest, so that the search task was not displayed until the participant had fixated directly on the cross for 1000 ms. The purpose of the fixation cross was to ensure that all the participants fixated on the same place on the screen at the start of each task to enable comparisons of scan path lengths and navigation patterns. When the target was located, the participants were asked to fixate on the target and push a button on the keyboard.

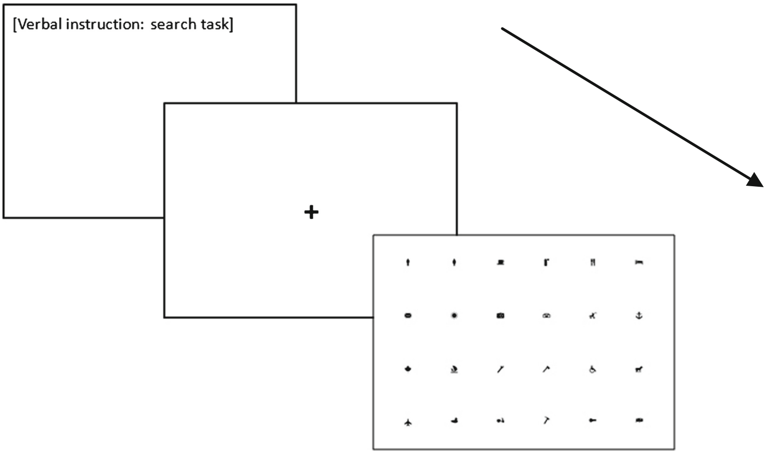

Fig. 1. Sequence of visual stimuli

The search tasks comprised of either visual stimuli containing icons (see Fig. 2) or textual stimuli containing words (see Fig. 3).

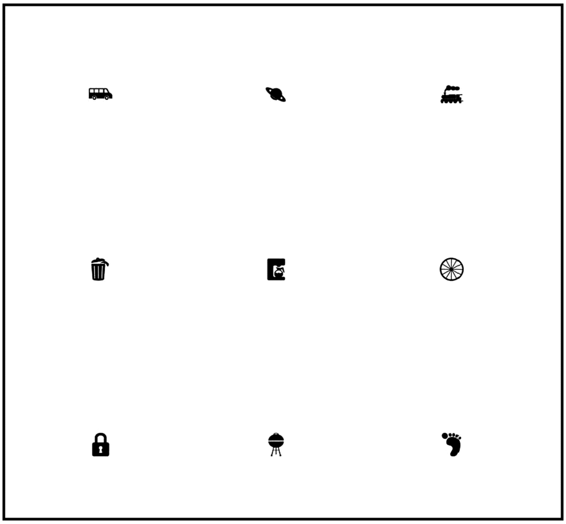

Fig. 2. Section from visual stimuli

All the displays included 24 items; one target item and 23 distractor items laid out in grids of six times four items. The visual stimuli contained black icons representing nouns (see Fig. 4) from the Noun Project (http://thenounproject.com/) released into the public domain under a Creative Commons license. The icon bank consisted of 99 icons, which had been screened by 64 library and information science students during the pilot testing. Only icons with a 100 % rater agreement were included as target icons.

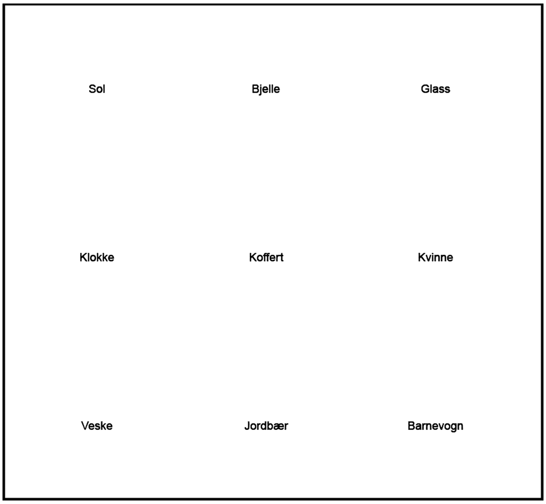

Fig. 3. Section from textual stimuli

The purpose of the screening was to avoid errors in the search tasks due to misinterpretations of the icons.

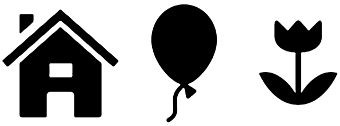

Fig. 4. Examples of icons

The textual stimuli contained Norwegian words equivalent to the nouns represented by the icons. All words consisted of 2 to 21 letters, written in black ink with 18 point Arial regular sharp font. The shortest and longest words were not included as targets, since they would stand out significantly from the rest of the words, which could potentially influence search times.

The icons and words were extracted randomly from an icon/word bank. Words and icons could appear in several stimuli, but icons or words used as targets were not used in subsequent tasks. The items in the displays were placed with a distance to ensure that the participants could not process more than one item per fixation (see Fig. 5).

2.5 Analysis

One of the icon tasks was removed in its entirety because several participants chose the wrong target (a calculator was misinterpreted for a telephone). Consequently, the matching word-task was removed to ensure an equal set of trials for each stimuli type. In addition, ten trials from each stimuli type were removed due to insufficient data quality. The final data set consisted of 904 trials; 452 for each stimulus, equally, distributed in the two participant groups.

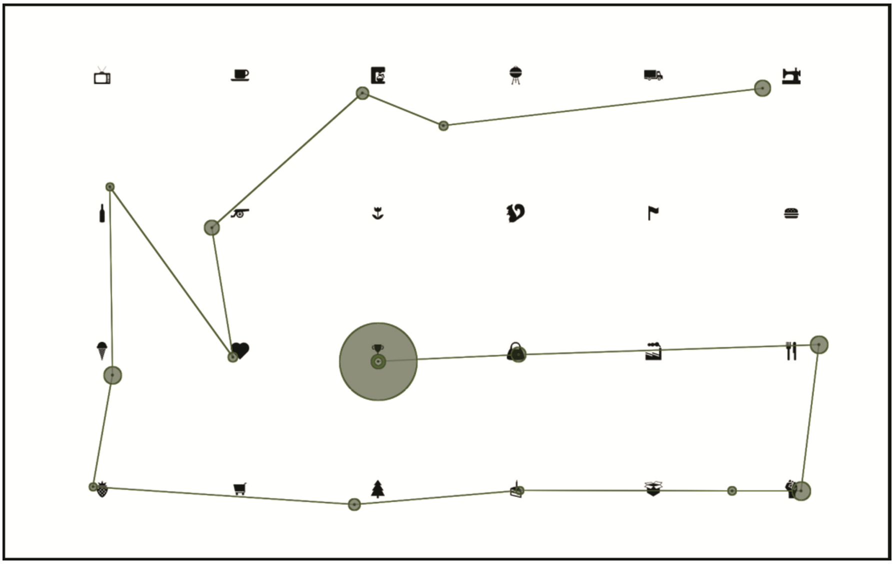

Fig. 5. Example of scan path in visual search task

3 Results

Search times in the icon displays were similar for both groups, $t(40) = 0.98$, $p = .33$. However, the students with dyslexia spent significantly longer time searching the textual stimuli ($M = 5.19$ s, $SD = 2.24$ s) than the control group ($M = 3.88$ s, $SD = 0.92$ s), $t(40) = 2.49$, $p < .02$, $d = 0.79$ (see Fig. 6). There were no significant differences in time usage between visual and textual tasks within the dyslexia group, $t(40) = 0.16$, $p = .84$. In contrast, the control group found the target significantly faster in the textual content ($M = 3.88$ s, $SD = 0.92$) compared to the visual content ($M = 4.93$ s, $SD = 1.16$), $t(40) = 3.28$, $p < .003$, $d = 1.04$ (see Fig. 6).

There were no significant differences in the eye data between the two groups in the visual tasks. However, in the textual tasks the dyslexia group had on average longer fixations ($M = 233.5$ ms, $SD = 40.1$ ms) than the control group ($M = 202.1$ ms, $SD = 3.8$ ms), $t(40) = 2.66$, p $< .02$, $d = 0.84$ (see Fig. 7). Except for the differences in fixation duration, the number of fixations and the saccades were similar in the two groups.

The users with dyslexia did not exhibit any differences in eye movements in the visual and textual tasks. In contrast, significant differences were found in both the fixations and saccades in the control group. Participants in the control group had significantly fewer textual stimuli fixations ($M = 15.3$, $SD = 3.8$) than in the icon stimuli ($M = 19.8$, $SD = 4.1$), $t(40) = 3.68$, $p < .002$, $d = 1.16$. Consequently, the number of saccades was correspondingly higher in the icon stimuli. Moreover, the average scan-path lengths were significantly longer in the icon task ($M = 5810.1$ px, $SD = 1286.3$) than the textual task ($M = 4370.2$ px, $SD = 1244.7$), $t(40) = 3.68$, $p < .002$, $d = 1.16$.

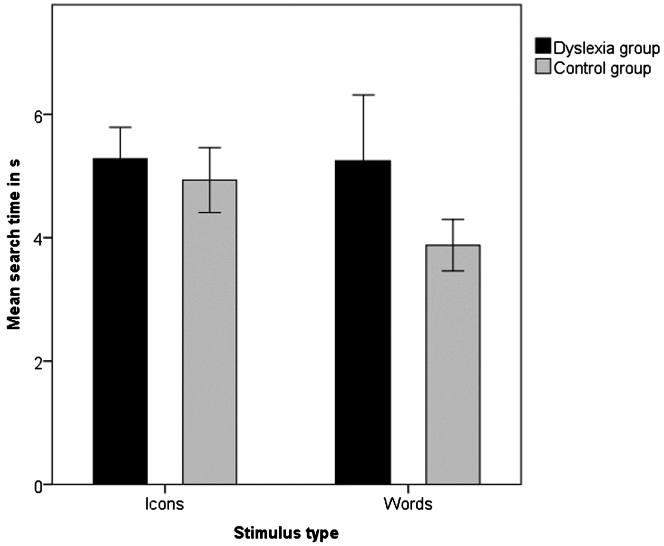

Fig. 6. Mean search times for visual and textual search tasks

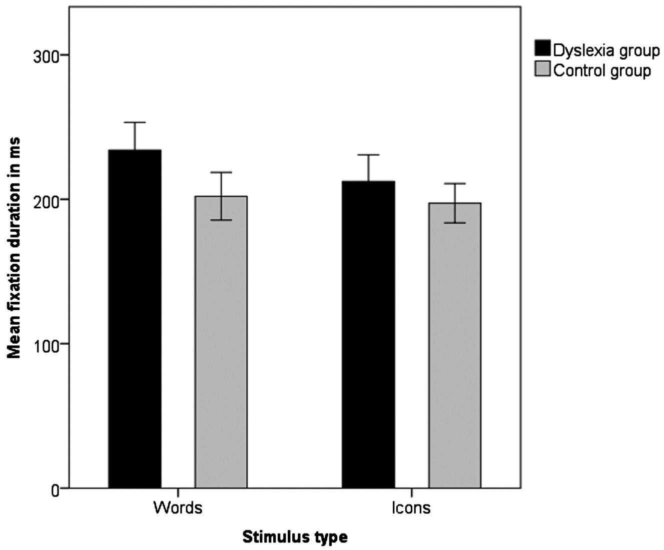

Fig. 7. Mean fixation duration for textual and visual search tasks

To get an indication of the effectiveness of the participants' eye movements, areas of interest (AOIs) were defined in the displays as either content or white space. There were no significant differences in percentage dwell times in these two types of AOIs between the users with dyslexia and controls in either icon tasks, $t(40) = 0.94$, $p = .35$ or textual tasks, $t(40) = 0.22$, $p = .83$. The participants in both groups fixated on approximately the same number of icons per task in the visual stimuli, $t(40) = 0.83$, $p = .41$.

Moreover, there were no significant differences in the number of words fixated on per task in the textual tasks, $t(40) = 0.72$, $p = .48$.

4 Discussion

Results from this study indicate that eye movements and performance levels between users with dyslexia and controls are quite similar in visual search tasks. Moreover, the users with dyslexia did not perform better in the visual tasks than the textual tasks. This finding contradicts the first hypothesis which assumed that users with reading impairments would perform best on the visual tasks.

Eye movements and time usage in the textual tasks were significantly different between the two groups. This result supports the second hypothesis, namely that controls would perform better than users with dyslexia in textual tasks. These findings may be partly explained by differences between processing images and reading. While perception of icons primarily depends on visual strategy, word identification also involves language decoding [12]. It is not surprising that the main differences are found in the textual tasks, since dyslexia mainly affects recognition and comprehension of written words [2]. The results from this study indicates that replacing text with icons will not reduce search times for users with dyslexia, but may be counterproductive for users without dyslexia.

Previous research has found that people with dyslexia usually exhibit longer fixation durations than users without dyslexia, both in reading sentences and single words [9], which is in accordance with this study. No significant differences were found between the two groups in the visual tasks, which may indicate that eye movements are more similar in the two user groups in such tasks. These findings contradict several studies which conclude that users with dyslexia are impaired in visual search tasks [10–15]. However, these differences may be due to experimental design, since this study did not follow the traditional search paradigm, but applied stimuli designed to resemble an icon-based graphical user interface.

Overall search times could possibly have been reduced if the participants were familiar with the icons before the trials. However, Greene & Rayner [20] suggested that if a user is presented with target and distractor items which are both either familiar or unfamiliar, the search rates are not affected. These findings may imply that familiarity with icons would not affect search times in this study.

Although this study indicate that searching visual stimuli is not more effective for users with dyslexia than searching text, it is possible that a combination of icons and text could facilitate the search process. A small set of recursive icons representing different media could be added to the textual content in result lists to enhance the browsing process. For instance, icons such as a news-paper representing news pages or speakers implying sound files could be included in search engines result lists. However, it has been suggested that the search performance among users with dyslexia decreases with an increasing set size [14]. Therefore, the consequences of introducing several modalities and an increased amount of content in a result list must be balanced against the benefit of introducing visual content. However, since most users seem to evaluate result lists linearly and only consider the top results [21, 22], it is possible that reducing the results per page may compensate for some size effect. More research is needed to conclude on the efficiency of such an interface.

5 Conclusion

The results from this study indicates that replacing textual content with visual content such as icons will not affect search performance among users with dyslexia. However, users without dyslexia will use more time on visual tasks than textual tasks. In visual search tasks such as those described in this experiment, users with dyslexia do not seem to be impaired compared to users without dyslexia, which contradicts findings in the more traditional visual search paradigm. However, this may be related to a task effect. More research is needed to investigate whether a combination of visual and textual content may enhance the search performance among users with dyslexia without reducing the search experience for users without dyslexia.

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References

1. Shaywitz, S.E., Shaywitz, B.A.: Dyslexia (specific reading disability). Biol. Psychiatry **57**(11), 1301–1309 (2005)
2. Snowling, M.J.: Dyslexia. Blackwell, Malden (2000)
3. Jeffries, S., Everatt, J.: Working memory: its role in dyslexia and other specific learning difficulties. Dyslexia **10**(3), 196–214 (2004)
4. Hiscox, L., Leonavičiūte, E., Humby, T.: The effects of automatic spelling correction software on understanding and comprehension in compensated dyslexia: improved recall following dictation. Dyslexia **20**(3), 208–224 (2014)
5. Snowling, M.J.: From language to reading and dyslexia. Dyslexia **7**(1), 37–46 (2001)
6. Mortimore, T., Crozier, W.R.: Dyslexia and difficulties with study skills in higher education. Stud. High. Educ. **31**(2), 235–251 (2006)
7. Smith-Spark, J.H., Fisk, J.E.: Working memory functioning in developmental dyslexia. Memory **15**(1), 34–56 (2007)
8. Macfarlane, A., Al-Wabil, A., Marshall, C.R., Albrair, A., Jones, S.A., Zaphiris, P.: The effect of dyslexia on information retrieval: a pilot study. J. Documentation **66**(3), 307–326 (2010)
9. Prado, C., Dubois, M., Valdois, S.: The eye movements of dyslexic children during reading and visual search: impact of the visual attention span. Vision. Res. **47**(19), 2521–2530 (2007)
10. Sireteanu, R., Goebel, C., Goertz, R., Werner, I., Nalewajko, M., Thiel, A.: Impaired visual search in children with developmental dyslexia. Ann. N. Y. Acad. Sci. **1145**, 199–211 (2008)
11. Boer-Schellekens, L.D., Vroomen, J.: Sound can improve visual search in developmental dyslexia. Exp. Brain Res. **216**(2), 243–248 (2012)
12. Huang, X., Jing, J., Zou, X.-B., Wang, M.-L., Lin, A.-H.: Eye movements characteristic of Chinese dyslexic children in picture searching. Chin. Med. J. **121**(17), 1617–1621 (2008)

13. Jones, M.W., Branigan, H.P., Kelly, M.L.: Visual deficits in developmental dyslexia: Relationships between non-linguistic visual tasks and their contribution to components in reading. Dyslexia **14**(2), 95–115 (2008)
14. Vidyasagar, T.R., Pammer, K.: Impaired visual search in dyslexia relates to the role of the magnocellular pathway in attention. NeuroReport **10**(6), 1283–1287 (1999)
15. Iles, J., Walsh, V., Richardson, A.: Visual search performance in dyslexia. Dyslexia **6**(3), 163–177 (2000)
16. Germanò, E., Gagliano, A., Curatolo, P.: Comorbidity of ADHD and dyslexia. Dev. Neuropsychol. **35**(5), 475–493 (2010)
17. Høien, T., Tønnesen, G.: Ordkjedetesten [The Word Chain Test]. Logometrica, Bryne (2008)
18. International Organization for Standardization: ISO 8596 Ophthalmic optics: Visual acuity testing – standard optotype and its presentation. International Organization for Standardization, Geneva (2009)
19. Zhang, P., Bobier, W., Thompson, B., Hess, R.F.: Binocular balance in normal vision and its modulation by mean luminance. Optom. Vis. Sci. **88**(9), 1072–1079 (2011)
20. Greene, H.H., Rayner, K.: Eye movements and familiarity effects in visual search. Vision. Res. **41**(27), 3763–3773 (2001)
21. Klöckner, K., Wirschum, N., Jameson, A.: Depth and breadth: first processing of search result lists. In: CHI 2004 Extended Abstracts on Human Factors in Computing, pp. 1539–1539. ACM (2004)
22. Cutrell, E., Guan, Z.: What are you looking for: an eye-tracking study of information usage in web search. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 407–416 (2007)