Reading Experiences and Reading Efficiency among Adults with Dyslexia: An Accessibility Study

Gerd Berget[1[0000-0002-1220-6239]] and Siri Fagernes[2[0000-0001-6524-5170]]

[1] Department of Archivistics, Library and Information Sciences, Oslo Metropolitan University, Postboks 4 St. Olavs plass, N-0130 Oslo, Norway
[2] Mobile Technology Lab, Department of Technology, Kristiania University College, Pb 1190 Sentrum, N.0170 Oslo, Norway
gerd.berget@oslomet.no

Abstract. Dyslexia is a common reading disorder that typically affects reading, concentration and short-term memory. Consequently, for people with dyslexia, reading fictional books might be challenging. Several studies have addressed lay-out and typography of digital texts. Less attention has been directed towards printed books. It has been suggested that e-readers might be beneficial for some people in this cohort. In this study, however, all the participants preferred reading fictional books on paper. This study investigates whether different line lengths affect reading experiences and reading efficiency of people with dyslexia. The overall purpose is to get a better understanding of how to produce accessible books. The experiments involve 20 adults reading excerpts from three fictional books in four different conditions where line length is the only independent variable. A screening-test for dyslexia was applied, in addition to eye-tracking and interviews. The findings indicate that the participants do not prefer narrow line lengths. However, the results show no significant impact of line lengths on reading speed or comprehension. The main conclusion is that line lengths seem to affect reading motivation, but not performance.

Keywords: Dyslexia, Line lengths, Reading.

1 Introduction

Dyslexia affects spelling and fluent word level reading [1]. This cognitive impairment is prevalent in approximately 7% of any population [2], with some variations between languages. The Norwegian written language has a frequent use of double consonants, silent consonants, consonant clusters, silent vowels, and words with irregular orthography, all of which people with dyslexia typically find challenging [3-5]. Consequently, learning to read can be demanding for many Norwegian children [4].

In Norway, the organisation *Books for Everyone* produces accessible literature in six different categories targeting various user groups (Table 1). The *Easy to Read* category comprises books written specifically for users who find reading challenging, for instance people with dyslexia, users with ADHD, non-native English speakers, inexperienced readers, or people who are ill. Such books are typically referred to as high-

This is a post-peer-review, pre-copyedit version of a conference proceeding published in HCII 2021: Universal Access in Human-Computer Interaction. Access to Media, Learning and Assistive Environments; 15th International Conference, UAHCI 2021, Held as Part of the 23rd HCI International Conference, Proceedings, Part II, which is part of the Lecture Notes in Computer Science book series (volume 12769). The final authenticated version is available online at DOI: https://doi.org/10.1007/978-3-030-78095-1_17

content/low-skills or high-interest/low-level books [6], hereby referred to as *Hi-Lo books*. Hi-Lo books typically have a reading level below the actual age of the reader, but address topics appropriate for the reader's age. Consequently, these books should not be mistaken for easy-to-read books for children learning how to read. Books in the *Easy to Understand* category are also modified in content, and the intended user group is people with severe developmental impairments. The remaining categories have modifications based on font sizes (*Big Letters*) or the inclusion of alternatives to plain text.

Table 1. Book categories applied by *Books for Everyone*.

Category
Easy to Read
Easy to Understand
Big Letters
Braille and Tactile Pictures
Sign Language and Norwegian with Sign Support
Alternative Communication Signs

In the production of Hi-Lo books, *Books for Everyone* alters various aspects of the books to ensure they are easy-to-read, e.g., using short sentences, avoiding long or complicated words, ensuring concrete content and keeping consistency between text and illustrations. Paper quality, typography and layout are also considered. Although Hi-Lo books are intended for various user groups, this paper will focus on one target group, namely people with dyslexia.

Typography has been reported to significantly affect accessibility for readers with dyslexia [7]. Several researchers have investigated how to best present text visually for people with dyslexia, addressing font types [7], font sizes [8], letter spacing [9], line spacing [10] and line lengths [11, 12]. However, most of these studies focus on reading on screen, less attention is directed towards printed books. Hi-Lo Books produced by *Books for Everyone* have a layout with a high frequency of very short line lengths, from approximately 10 characters and up (Fig 1). The purpose is to enhance the reading experience by providing small amounts of text at a time. According to representatives from *Books for Everyone*, the reason for this layout is the assumption that it makes the text more accessible for people with reading impairments. However, applying short line lengths implies that even relatively short sentences are split over several lines (Fig. 1, first and second sentence), requiring vertical eye movements in the middle of a sentence. Consequently, the reader must remember the text before the line shift until continuing reading the next line.

Dyslexia is often associated with reduced short-term memory capacity [13]. It is also claimed that the eye movements follow a different pattern compared to readers without dyslexia. However, Starr and Rayner [14] suggest that the reading impairment associated with dyslexia may cause irregular eye movements, not the other way around. The purpose of this study is to investigate whether short line lengths support the reading of people with dyslexia, or whether having sentences spread over several lines makes the

text more difficult to read. This study is motivated by the assumption that frequent line shifts and numerous vertical eye movements within sentences may interfere with the reading fluency. Moreover, if the reader must re-read a sentence (e.g. due to forgetting content or decoding errors), longer vertical eye movements are required to navigate back to the beginning of the sentence. This study explores the following research questions:

RQ_1: Do line lengths affect the reading experience for people with dyslexia?
RQ_2: Do line lengths affect the reading efficiency for people with dyslexia?

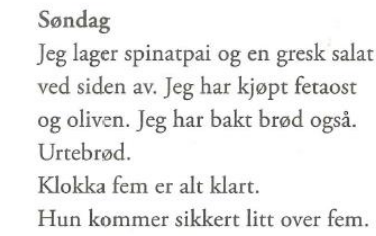
Søndag
Jeg lager spinatpai og en gresk salat
ved siden av. Jeg har kjøpt fetaost
og oliven. Jeg har bakt brød også.
Urtebrød.
Klokka fem er alt klart.
Hun kommer sikkert litt over fem.

Fig. 1. Lindkvist [15], excerpt from page 17, reproduced with permission.

Reading experience comprises subjective measures acquired from qualitative interviews. Reading efficiency is commonly associated with reading speed, and has been applied as a measure either alone or combined with other units for decades [16]. High reading speed, however, does not necessarily entail successful reading, since comprehension is also important [16, 17]. According to Perfetti [18], reading efficiency may be regarded as a ratio of outcome to effort, where time is the proxy for effort. It is argued that the ability to retrieve words is more important than speeds. In this study reading efficiency is related to a combination of objective scores from reading experiments, namely reading speed (words per minute) and reading comprehension (number of correct answers about the previously read content).

2 Background

Dyslexia occurs in many forms and severities, and the definition is still under debate [19]. However, there seems to be consensus that dyslexia is related to challenges with fluent or accurate word recognition and spelling, and affects reading comprehension [20]. Other common cognitive markers are impaired short-term memory capacity [13] and reduced concentration [21]. One of the main challenges for people with dyslexia is reading long texts [22], such as books. Consequently, there is a need to consider how to produce accessible books, with the aim to facilitate the reading process.

2.1 Accessibility and Universal Design

Producing accessible books, such as the *Hi-Lo* books developed by *Books for Everyone*, represents an inclusive strategy, where the aim is to provide low proficient readers with

suitable and accessible materials that hold a high literary quality. However, accessibility in general, and modified books in particular, are scarcely discussed in the research literature. Thiessen and Dyson [23] reported that children with dyslexia prefer books that resemble books read by their peers over books that are regarded as easier to read by typographic convention. This finding is in accordance with Berget and Fagernes [24], who found that adults with dyslexia in general were sceptical towards books that appeared to be modified because the books "*looked like elementary school books*" and "*they did not want to feel stupid*". The same finding was reported by Brante [25]. Consequently, it seems like the universal design perspective might be more purposeful.

Universal design concerns designing and developing products, services and environments so that they can be used by everyone, regardless of their level of functioning. One of the goals of universal design is to avoid adapted solutions for people with specific impairments, but rather design user-friendly solutions for 'everyone'. Motivations for universal design are manifold, such as human rights, social inclusion, and the ability for everyone to participate in the society on equal premises [26-28].

2.2 Reading Skills

Leisure reading is considered important to develop social skills such as empathy [29] and improve reading skills, especially for users with reading impairments [30]. According to Gambrell [31], students will never reach their full literacy potential without a high reading engagement. Gambrell [31] defines motivation to read as "*likelihood of engaging in reading"* and emphasises the importance of promoting intrinsic motivation. Further, Gambrell [31] suggests seven rules of engagement, including "*students will be more motivated if they have opportunities to be successful with challenging texts"*. The reader is likely to give up reading if the text is too difficult, but also if it is too easy. Moreover, according to Schunk and Zimmerman [32], self-esteem might be an important factor related to reading experience and efficiency.

Low self-esteem is reported as a key issue for both children and adults with dyslexia in general [33-35], and females in particular [36]. In the context of reading, Gambrell [31] reported that all students would like to be perceived as reading challenging books, and people with reading impairments often choose books for pleasure reading that are too difficult to read. Consequently, Gambrell [31] recommends to not label books as *easy*, *average* or *difficult*, since the people who would benefit from reading the "easy books" would probably avoid them.

Becker and McElvany [37] found that children who enjoy reading as a leisure activity read frequently and develop good reading skills. In contrast, children who read primarily because of extrinsic motivation have less developed reading skills. Consequently, it seems important for children with dyslexia to have access to books they have an intrinsic motivation to read. Based on the assumption that this also applies to adults with dyslexia, the main purpose of this study is to gain an understanding of how to develop books that motivate adults with reading impairments to read. According to Becker and McElvany [37] the reason why people with reading challenges do not succeed in their reading may not always be lack of motivation. The challenges might also be a result of previous experience of little or no progress in enhancing reading skills. It

is therefore important to develop books that give a sense of coping, but at the same time increase in complexity and difficulty.

Leinonen and Müller [38] studied the reading habits of adults with dyslexia and found a relationship between reading speed and frequency of reading, where the faster readers read more in their everyday lives. Moreover, teaching people with dyslexia faster reading styles might be important to keep the person motivated to read. A relevant measure often applied in this context is reading fluency, a measure that has been defined differently over the years. However, Wolf and Katzir-Cohen [39] argue that reading fluency should be regarded as both component-based and developmental-based, where reading rate and speed are subskills of reading, while automaticity and accuracy result from reading and reading fluency.

Memory was early assumed to play a vital part in reading, and it has been suggested that differences in working memory may be reflected in reading comprehension [40, 41]. Short-term memory represents an important contributor to reading comprehension [42], from the basic level of reading letters and assembling them into words to remembering previously read words and putting them together in a sentence. Finally, previously read content must be recalled, so the new sentences can be put into a context. People with dyslexia typically have reduced short-term memory capacity [13], causing additional challenges with reading comprehension.

2.3 Layout and Typography

The impact of physical characteristics of a text, and how those affect reading has been discussed for decades. Samuels and Eisenberg [43] point out that these characteristics may influence reading speed, the nature of eye movements and overall reading strategy. According to Rello and Baeza-Yates [7], the layout and typography of a text is fundamental for people with dyslexia. Several researchers have investigated which layout and typography that best accommodate users with dyslexia primarily addressing reading on screen. Moreover, Jackson [44] reported that most of the research related to typology has been conducted on participants under 18 years, and often younger children. Consequently, there is a need to look further into these issues in the adult population with dyslexia.

It has been argued that there are benefits for people in general to read in a printed over digital format, especially in the context of learning [45], and for some users with dyslexia [46]. An advantage of screen reading is the possibilities for personalization, such as adjusting font sizes or zoom in on certain content. Nevertheless, previous research has reported overwhelming preferences for printed books over digital media [47, 48]. Moreover, students who read texts on paper have been reported to receive better reading comprehension scores than students who read digitally [49].

Typography has been discussed in the context of dyslexia. It has been suggested that fonts without serifs are most accessible, both on paper [50] and screen [7]. Rello and Baeza-Yates [51] found that sans serif, monospaces and roman font styles improved reading efficiency on screen, while serif, italic and proportional fonts were not optimal.

Special font types for people with dyslexia have also been developed, for instance *Sylexiad*, aimed at adult readers with dyslexia [52], *OpenDyslexic* and *font Dyslexie*

[53]. Marinus and Mostard [54] tested the readability of *font Dyslexie* and concluded that it was not the shape of the letters, but the spacing between the letters, that benefited users with dyslexia. Zorzi and Barbiero [9] concluded that extra-large spacing between printed letters supported readers with dyslexia. In the context of screen reading, Rello and Pielot [10] concluded that line spacing had no effect on digital readability.

According to O'Brien and Mansfield [8], people with dyslexia rely on larger letters than readers without dyslexia to accomplish maximum reading speed. The British Dyslexia Association [50] recommends 12-14-point font size, and suggests that some users with dyslexia might prefer even bigger fonts. Rello and Pielot [10] reported that font size has a significant effect on the readability and comprehension of a text and suggest 18-point font size.

Few studies address line lengths. For books in general, line lengths should not surpass 70 characters [55]. However, according to Davidov [56], common line lengths in books are 80-100 characters. Bernard and Fernandez [57] looked at the differences between adults and children regarding line lengths (not including participants with reading impairments) while reading digital texts. They found no differences in reading times or efficiency for either groups. However, medium line lengths (55 characters per line) were considered optimal for reading.

Schneps and Thomson [12] studied people with dyslexia and their use of e-readers. In a POD condition, the text was on average displayed with line lengths of 12.7 characters per line, compared to 67.2 characters in a PAD condition. Schneps and Thomson [12] concluded that shorter lines could be beneficial. This finding contrasts with the guidelines from British Dyslexia Association [50], recommending 60-70 characters per line. Rello and Baeza-Yates [11] investigated reading on screen and concluded that line lengths had no significant effect on the readability for people with dyslexia. Moreover, some participants preferred wide columns, because the text seemed shorter [11]. Consequently, typography may not only affect readability, but also motivation.

3 Methods

This study applied a within-subjects design, using a triangulation of methods, namely screening tests, interviews, and reading experiments involving eye tracking equipment.

3.1 Participants

The study comprised 20 people based on the following inclusion criteria; age above 18 years and a formal diagnosis of dyslexia. Participants could not rely on reading spectacles, since glasses would interfere with the eye tracking equipment. A total of 22 participants were recruited. However, two people were excluded because of too high scores on the dyslexia screening test. No control group was included, since the purpose of the study was to investigate the accessibility of adapted books targeted specifically at readers with dyslexia.

Participants were mainly recruited through the organisations *Books for Everyone* and *Dyslexia Norway*. The participants (Table 2) were aged between 18 and 40, with an

average age of 26.2 years. The gender distribution was 11 females (55%) and 9 males (45%). No participants had any relations to the experimenters.

Table 2. Participant characteristics.

Participant	Gender	Age	Educational level
P1	Male	25	Bachelor of Information Technology
P2	Female	29	Bachelor of Arts and Design
P3	Female	36	Bachelor of Information Technology
P4	Female	30	Bachelor of Preschool Education
P5	Male	40	Completed apprenticeship
P6	Female	25	Master of Education
P7	Female	22	Student (3rd year Bachelor of Business)
P8	Female	23	Bachelor of Economics
P9	Male	22	Upper secondary school
P10	Male	35	Completed apprenticeship (carpenter)
P11	Male	26	Student (3rd year, Bachelor Paramedics)
P12	Male	23	Student (1st year, Bachelor Information Technology)
P13	Male	28	Completed apprenticeship (helicopter technician)
P14	Female	23	Student (1st year Bachelor Information Technology)
P15	Male	22	Student (1st year Bachelor Information Technology)
P16	Female	18	Student (1st year Bachelor Nursing)
P17	Female	18	Upper secondary school pupil (3rd year)
P18	Male	19	In apprenticeship (2nd year electrician)
P19	Female	23	Student (1st Bachelor of Library- and information science)
P20	Female	37	Bachelor of Library- and Information Science

3.2 Procedure

Each session lasted for approximately one hour and followed the same procedure for all participants. First, participants got general information about the study and signed a consent form, followed by registration of background data such as gender, age and diagnoses.

Two screening tests were then conducted, one for visual acuity and one for dyslexia. A Landolt C visual acuity test was applied at a distance of 40 cm for short vision, according to the European Standard [58]. The purpose of the test was to ensure that the reading efficiency was not affected by reduced or blurred vision. The inclusion criterion was set at a visual acuity of 0.8 with both eyes open, within limits of what is regarded as normal vision [59]. A Norwegian Word Chain Test [60] was applied to screen for dyslexia. The purpose of this test was twofold; to confirm the diagnosis without accessing sensitive diagnostic papers, and to provide information about the decoding skills of each participant.

The participants were interviewed about their general reading habits and their preferences of the design and layout of printed books. After freely discussing characteristics affecting their motivation to read a book and which criteria they used when selecting a book, the participants were presented with six attributes (number of pages, number of illustrations, amount of text per page, line lengths, font type and font size) and asked to rate them from most to least important. Each interview was succeeded by a reading experiment. The participants wore SMI eye-tracking glasses 2 Wireless (SMI ETG 2W) through the entire reading session. Eye movements were recorded with a tracking ratio of 60 Hz. The sound recorder option was activated.

The participants read texts from all books in four different line lengths. Each text was read once, in one condition only. The participants read the texts silently in their own pace. After completing each text, the participants answered two questions about the content. All questions had been piloted and modified to ensure equal levels of difficulty. In the post-interview, participants were asked about overall preferences for each condition, with the purpose of getting subjective measures of the reading experience.

3.3 Stimulus

The stimulus comprised twelve texts and included four pages each from three different fictional novels in the *Books for Everyone* category *Easy to Read*. Every page had been selected so the story would make sense without reading the whole book. It was also important to ensure that the pages were equivalent in terms of length and reading level to enable comparisons between conditions. The excerpts were therefore analysed according to word count. In cases where the pages did not have an equal number of words, the text was slightly edited by removing the exceeding number of words, typically adjectives. This revision did not affect content or reading level.

The books were analysed according to the use of compound words, double consonants, silent consonants, consonant clusters, silent vowels and words with irregular orthography. The purpose was to ensure an even distribution of linguistical elements that people with dyslexia typically find challenging [3-5].

The texts were printed in black ink on pearl white 130-gram paper in A4-size based on the recommendations by the British Dyslexia Association [50] to avoid large contrasts between text and background. The font type Arial was used, a font-type without serifs which is frequently suggested to be accessible for people with dyslexia [7, 50]. The font size was 14 points, corresponding with the font size originally applied in the books. This size is also recommended by the British Dyslexia Association [50] and applied in other studies e.g. Zorzi and Barbiero [9]. The layout comprised left-justified text with ragged right edge, which is commonly reported to be beneficial for people with dyslexia [50].

Each text was printed in four conditions, where line length was the only independent variable. The line lengths were either 40, 60 or 80 characters including white space, hereby referred to as L40, L60 and L80 (Fig. 2) In addition, the original, unmodified version by Books for Everyone was included, hereby referred to as BfE. The line length of 60 characters was based on guidelines by the British Dyslexia Association [50],

recommending 60-70 characters, while 40 and 80 were based on studies such as Rello and Baeza-Yates [11].

Fig. 2. Excerpts from stimuli (Lindkvist, 2013: p. 17) in the four conditions, reprinted with permission.

Six experimental folders were assembled where books and conditions appeared in different orders. However, all pages from the same book were read in sequence and ascending order, to avoid frequent shifts in writing styles and content. The condition for each text varied, but all books were represented in every version in the document corpus. Each participant got one folder, and the folders were equally distributed among the participants.

3.4 Analysis

Data from the interviews addressing reading habits and preferences were categorised and analysed qualitatively. Preferences from the post-interview were used as subjective measures for reading experience. Reading efficiency measures were acquired from the reading experiments and analysed quantitatively. Reading speed and comprehension scores were used as objective measures of reading efficiency.

For each participant, reading speed (words read per minute) was computed for each read text based on the eye-tracking recordings. One of the goals was to investigate whether the text format with respect to line lengths affected the reading efficiency of the users. Consequently, the mean and median reading speeds were computed, as well as the total amount of correct answers given for each text format. The latter was used as a measure of reading comprehension. The use of measures for objective readability, objective comprehensibility and subjective preferences is in accordance with the study by Rello and Baeza-Yates [11].

Finally, it was tested for correlation between reading speed and line lengths for the different formats. The BfE format does not specify any standard line lengths, which implies that the line lengths vary. The estimated reading speeds of this format were hence not included in the correlation tests. For subsets of the data with very large variation in reading times, the eye-tracking data was visually inspected to investigate whether any particular behaviour stood out.

3.5 Ethical Considerations

The project was approved and ethically screened by the Norwegian Centre for Research Data (project number 50953). All data was anonymised. Participants could withdraw from the study at any time without justifying the decision.

4 Findings

4.1 Pre-Interviews

In the context of reading habits, 11 participants rarely or never read fictional books, 2 of which had never read a whole book. While 3 people read on a monthly basis, only 6 participants read daily or weekly. Several participants expressed a wish to read more. Of the participants who read frequently, 2 people referred to this as an intentional strategy to improve reading skills.

When reading fictional books, all participants preferred reading in printed format. Their main justification was either concerned with e-books being tiresome to read or related to compensating strategies. Several participants mentioned using a white paper or their finger as navigational support while reading, a strategy they found difficult to apply when reading digital media.

The participants mentioned several characteristics of books that affected their motivation to read. Typography was the most frequently mentioned issue. 10 participants emphasised different perspectives on white space, between words, lines or paragraphs, the amount of text on each page and/or the total amount of white space on each page, while 6 mentioned either font type, font size or both. Easy language ("*but not too easy*") was mentioned by 9, while 8 focused on the actual content, such as "*a catchy topic*", the blurb, genre or title. Design was mentioned by 8 persons, with a focus on the cover and illustrations. Some relied on recommendations by others or the reputation of the book or author, a criterion mentioned by 7 of the participants. The structure of the book was mentioned by 4 people, such as a preference for short paragraphs or chapters, while only 1 person mentioned number of pages of the book.

When asked to rank 6 specific attributes (Fig 3), text per page was ranked as the most important aspect by 7 participants, 3 emphasised either number of pages, font type or font size, while 2 ranked illustrations or line lengths at the top. There was more cohesion regarding the aspect considered least important. In total, 11 people considered illustrations as least important, 6 the total number of pages and 3 font type. None of the three remaining categories were ranked last.

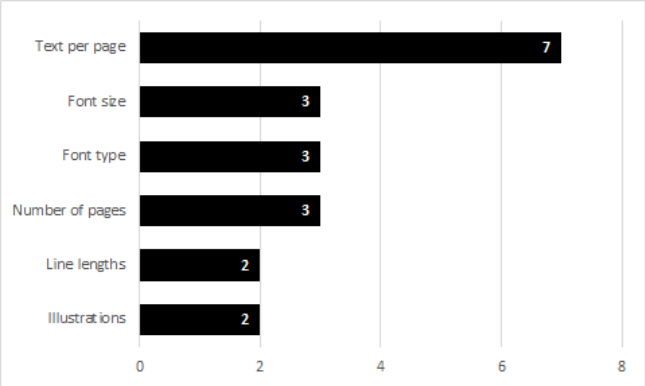

Fig. 3. Characteristics considered important when selecting a book

The rankings were averaged across all participants (Table 3), where the attributes considered most important received the lowest scores (1 being top ranking). The total amount of text per page and line lengths were considered most important, followed by font size and type. Number of pages and illustrations were rated as least important.

Table 3. Attributes scored according to importance (1 being top ranked).

Attribute	Score
Text per page	2.3
Line lengths	2.9
Font size	3.2
Font type	3.3
Number of pages	4.5
Illustrations	4.9

4.2 Reading Experiment

The measured reading speeds varied among the participants with respect to which format resulted in the shortest and longest reading time, but also regarding the computed reading speed across conditions. A comparison of average reading speeds for each condition for all participants showed little variation between the mean values (Table 4). L60 and L80 seem to generate slightly faster reading than the BfE and L40 format. The standard deviations are also comparable in size.

As the participants varied with respect to their score on the Word Chain Test, they were divided into ‘subgroups’ based on their individual scores. The groups were based on percentiles, so that participants in group 1 had test scores within the 25th percentile, group 2 within the 50th percentile and so on. The overview of groups, number of participants in each group and the range of test scores are presented in Table 5. The quantitative measures, mean and median reading speed, were also computed for each individual group.

Table 4. Reading speeds for all participants

Condition	Reading speed (mean)	Reading speed (median)	Range (min, max)
BfE	141 (SD: 40)	139	(60, 222)
L40	141 (SD: 44)	138	(46, 222)
L60	148 (SD: 53)	141	(52, 280)
L80	142 (SD: 48)	130	(48, 253)

Table 5. Grouping of participants based on test scores

Group #	Scores	Participants
1	12, 18, 21	P3, P4, P5, P10, P14, P20
2	26, 31, 32, 33	P13, P16, P17, P19
3	34, 37, 38, 39	P2, P7, P11, P12, P15, P18
4	40, 49, 51	P1, P6, P8, P9

Comparing the mean reading speed for each group did not provide any clear patterns with respect to which format resulted in the best reading efficiency. Comparisons of the values for the different groups (Table 6-9) show that the reading speed on average is higher in the groups with higher scores on the Word Chain Test. For the group with the lowest test scores (Table 6) and the group that scored within the 75th percentile (Table 8), L60 resulted in the highest mean value of reading speed, while the BfE format gave the best results with respect to mean reading speed in group 2 (Table 7) and 4 (Table 9).

Table 6. Reading speeds for group 1 (25^{th} percentile)

Condition	Reading speed (mean)	Reading speed (median)	Range (min, max)
BfE	116 (SD: 36)	111	(63, 192)
L40	124 (SD: 50)	112	(46, 208)
L60	129 (SD: 67)	112	(52, 280)
L80	126 (SD: 56)	120	(48, 236)

Table 7. Reading speeds for group 2 (50^{th} percentile)

Condition	Reading speed (mean)	Reading speed (median)	Range (min, max)
BfE	144 (SD: 27)	139	(122, 222)
L40	132 (SD: 28)	130	(92, 189)
L60	139 (SD: 28)	128	(102, 200)
L80	133 (SD: 29)	128	(92, 189)

Table 8. Reading speeds for group 3 (75th percentile)

Condition	Reading speed (mean)	Reading speed (median)	Range (min, max)
BfE	155 (SD: 38)	155	(82, 221)
L40	163 (SD: 40)	168	(97, 222)
L60	169 (SD: 45)	163	(92, 236)
L80	158 (SD: 49)	155	(88, 236)

Table 9. Reading speeds for group 4 (100th percentile)

Condition	Reading speed (mean)	Reading speed (median)	Range (min, max)
BfE	156 (SD: 42)	175	(95, 200)
L40	143 (SD: 44)	152	(82, 210)
L60	154 (SD: 52)	133	(104, 270)
L80	152 (SD: 47)	146	(96, 253)

Correlation was checked between mean reading speed and line lengths for each compared format, both overall, and for each participant group. The results indicated no or little correlation (approximately zero) for all participant groups. Summarizing the number of correct answers also did not differ much between the different layouts.

The reading efficiency for each format for each participant was also compared with the preferred reading format. Several of the participants (P1, P3, P8, P12, P13, P14, P16) preferred the wider formats L80 and L60, and disliked the BfE format, but actually read faster when the book pages were formatted in the BfE style. Another group of participants (P4, P6, P7, P9, P15, P20) both preferred and read fastest when the texts were in one of the wider formats (L60 and L80).

4.3 Post-Interviews

L80 and L60 were ranked as the preferred format by 9 participants, while 2 preferred L40. No participants preferred the BfE format. Regarding the least preferred format, 12 people ranked the BfE version last, followed by L80 rated by 4 people, while L40 and L60 were voted last by 2 people each. The preference scores for line lengths were also averaged (Table 10). Top ranked formats got a value of 1, while least ranked format got 4. Again, the longest lengths (L80 and L60) were preferred over the shorter lines (L40 and BfE).

Table 10. Ranking of preferred line lengths (1 being top marked)

Format	Average rank
L80	1.8
L60	1.95
L40	2.7
BfE	3.55

The participants discussed several aspects of line lengths, with a main focus on four perspectives, namely navigation, reading fluency, reading experience and self-esteem.

Navigating the text was fundamental for many participants, and often related to punctuation and eye movements. A majority emphasised sentences as the most important unit, and the placement of the punctuation seemed more essential than the line lengths. Several participants mentioned that it was more important where in the sentence they had to navigate to a new line than how much content they had read before doing so. It seemed most vital not to split sentences over many lines.

The participants emphasised that it should not take too much effort to navigate between sentences or back to the beginning of a sentence. One participant said: "*I prefer when sentences end at one line and are not spread over several lines. In the original* [BfE] *it became difficult to navigate back to the beginning*" (P9). Another participant related a preference for L60 to eye movements: "*If I have to reread, I can just move my eyes back, not up and down*" (P18). A different participant stated that L40 and L60 "*had sufficient line lengths which makes it possible to keep pace with my eyes*" (P4). This participant often lost the overview during line shifts and always double-checked that she was navigating the text correctly when sentences were split over several lines.

Participants seemed to prefer longer line lengths than the BfE format provided. However, too long lines (L80) would make navigation difficult due to the horizontal distance they had to move their eyes. One participant elaborated on this issue: "*this version is too dense, then I will navigate to the wrong line, I will be utterly confused, and have to reread sentences*" (P19).

Regarding reading fluency, most participants did not favour the BfE version because the sentences were split over too many lines. This typography often led to many line shifts (and more vertical eye movements) per sentence, causing a halting reading: "*This one* [BfE] *is annoying, it doesn't flow as well because you have to move your eyes so often* […] *it is easier to read when the lines are so long that I don't have to shift line that often*" (P18). Another participant stated: "*with lines with one or few words, the reading becomes very staccato*" (P9). Others got confused about the genre, believing that the BfE version was poetry: "*I get a very poem-like feeling of the adapted* (BfE) t*ext. I do not like reading that* […] *it affects my reading flow*" (P17).

Many participants discussed the overall reading experience. One participant said: "*the adapted* (BfE) *version kills fiction*" (P11), and thought the text seemed fragmented due to the short lines which negatively affected the reading fluency and reading experience: "*where is the love of reading then*?". Another participant tied the short sentences to emotions: "*I cannot manage to get feelings from short sentences*" (P17).

Other participants mentioned a close relationship between the structure of the text and memory: "*I did not like it when the lines became very short,* (it was) *difficult to focus. It became so fragmented that it was hard to remember things from the start until the end.* […] *When reading the short lines, it was difficult to grasp the content*" (P7).

Several participants mentioned that the BfE version reminded them of elementary school books, and that they preferred books resembling the books read by their peers: "*It should not be obvious that this book is made for someone with dyslexia. You shouldn't have to feel different*" (P7). Another participant stated that this format

affected the motivation: "*If they try to stupefy the text too much, it doesn't encourage to reading*" (P11), while another said "*I associate this version* [BfE] *with elementary school, then I don't want to read it*" (P17) and "*one doesn't want the text to be so adapted that one feels stupid*" (P10).

5 Discussion

RQ1 addressed whether line lengths impact the reading experience of people with dyslexia. The participants were quite unanimous in their perceptions that short line lengths negatively affected reading flow and reading experience, and hence also the motivation to read. Most participants preferred longer line lengths (L60 and L80). Moreover, longer line lengths resulted in fewer lines overall, giving the visual impression that the text was shorter. This finding corresponds with Rello and Baeza-Yates [11]. These results support the guideline by the British Dyslexia Association [50] to avoid narrow columns and correspond with the IFLA (International Federation of Library Associations and Institutions) easy-to-read guideline stating that sentences should fit on a single line [61].

It also seems purposeful to direct attention towards navigation during reading, which is a topic for further research. Decoding errors occur frequently among people with dyslexia [20]. Consequently, it might be especially important to consider how to support navigation between sentences. Challenges relating to remembering content during frequent line shifts were also mentioned, suggesting that impaired short-term memory might affect the reading experience.

Another issue mentioned by most participants was the impact of frequent line shifts in the middle of sentences, causing a halting reading. This finding supports the assumption that line lengths can affect how a text is read [43]. Since intrinsic motivation [31] and progress [37] are reported to be important factors in developing reading skills, overall reading experience should be addressed in future research.

The finding that the Books for Everyone books were perceived as "stupefied" is in accordance with other studies on reading and motivation, suggesting that it is important that books targeted at people with reading impairments are not conceived as different from other books [23, 31, 32]. This is particularly important since people with dyslexia often seem to have reduced self-esteem [33]. This finding supports the universal design paradigm, where the products are usable for all types of users, and not particularly designed for one user group. This is also the overall purpose for Books for Everyone. For instance, Easy to Read books are developed for a diversity of users who might find reading challenging for various reasons. Consequently, by producing books that appeal to a wide spectrum of user groups, the need for "special books" would no longer exist. However, more research is needed on how to develop such books. It has been suggested that making products accessible for people with dyslexia typically benefit other users as well [62], which makes further studies on readers with dyslexia purposeful within the universal design context.

RQ2 addressed the relationship between line lengths and reading efficiency. To summarise the findings related to reading efficiency, which involves taking both reading

speed and comprehension into consideration, this study has not been able to detect any clear patterns regarding which of the compared formats that result in the best performance, at least when each of the sub-groups of participants are studied individually (Table 6-9). For the entire group, however, L60 resulted in the highest reading speed among the participants, both with respect to mean, median and maximum number of words per minute. The large standard deviations associated with the calculated means may indicate that there are other aspects than the format with respect to line length that affect the reading speed.

The results of this study indicate no effect of line lengths on reading efficiency, neither in reading times nor in comprehension. This finding contradicts Schneps and Thomson [12]. The study comprised e-readers, and the studies are not directly comparable. The results, however, seem to be in accordance with Rello and Baeza-Yates [11], although that study was also conducted on a digital platform.

Regarding reading habits of adults with dyslexia, the participants rarely read fictional books or spent time on leisure reading, confirming the findings by Leinonen and Müller [38]. Several participants expressed a desire to read more but did not have the energy because other tasks were demanding, such as studying. Leisure reading is reported to be especially important for people who find reading challenging [30], but users need to develop fast enough reading speed and reading styles to keep motivated to read [38]. Moreover, people with reading challenges do not seem to read less because they lack motivation, but because they do not perceive progress [37]. Consequently, it is important to look further into how to provide such skills and among people with dyslexia. This is also a key issue for adults who have finished school and are not attended to by teachers and/or school librarians. Relevant topics to address in future research would be compensating strategies to make reading more efficient and how to produce accessible books targeted at adult readers.

Previous research on reading and dyslexia has mainly addressed digital formats [11-12]. It has been suggested that e-readers might be beneficial for some people in this cohort [46]. However, in this study all the participants preferred reading fictional books on paper. This finding is in accordance with research on reading in general, that reading printed books is more beneficial than digital books [47-49]. Moreover, the results suggest that more research is needed on layout and typography on printed books for people with dyslexia.

The pre-interviews produced data on motivational criteria for selecting a book to read. Based on the findings in this study, it seems reasonable to assume that the amount of white space in general is important. This finding is in accordance with guidelines on both accessibility on digital [62, 63] and printed formats [50]. The number of pages, however, was not regarded as relevant. This was surprising, since people with dyslexia typically spend much time reading a text [20] and oftentimes have challenges with concentrating on a task for a long time [21].

Finally, from the pre-interviews it was apparent that the participants were very diverse with respect to the amount of reading experience. While some participants hardly read anything for leisure, others stated that they enjoyed reading, and would read up to several hours a day. Some participants had very little or no higher education, while others had completed bachelor or master’s degrees. As the amount of reading

experience is expected to have significant impact on reading efficiency, it seems likely that this factor may be one of the explanations to the large standard deviations in the computed means of reading speed in this study.

6 Conclusion

Based on this small-scale study, line lengths might impact the reading experience of users with dyslexia, affecting reading fluency and the motivation to read, and may be worth investigating further in a large-scale study including a control group. In contrast, line lengths might possibly not affect reading efficiency. In the context of line lengths and fiction, it might be most purposeful to consider user preferences over reading efficiency, to ensure the production of books that people with dyslexia are motivated to read.

Some key issues require particular attention in future research. First, intrinsic motivation is very important to support the reading of people with dyslexia. Second, there is a need to design books that better support navigation between sentences for people with impaired short-term memory. Moreover, there is a need for research on how punctuation and the layout of sentences may affect reading efficiency. Further, the preferences for printed books implies a need for more research on how to make printed text readable for people with dyslexia.

Due to a limited number of participants, it is not possible to generalise the findings from this study. Further, the participants read excerpts from books. The results might have been different if they for instance had read an entire book from start to finish. However, since reading is an especially demanding task for people with dyslexia, such an experiment would have had to be conducted in several sessions over a long period of time.

References

1. Nergård-Nilssen, T., Hulme, C.: Developmental Dyslexia in Adults: Behavioural Manifestations and Cognitive Correlates. Dyslexia 20(3), 191-207 (2014).
2. Peterson, R. L., Pennington, B. F.: Developmental dyslexia. Lancet 379(9830), 1997-2007 (2012).
3. Helland, T., Kaasa, R.: Dyslexia in English as a second language. Dyslexia 11(1), 41-60 (2005).
4. Lyster, S.-A. H.: Reading development and reading disabilities: Focus on Norway. In Scruggs, T.E., Mastropieri, M.A. (eds) International Perspectives, pp. 21.55. Emerald Group, Bingley 2007.
5. Høien, T., Lundberg, I: Dysleksi: fra teori til praksis [Dyslexia: from theory to practise]. Gyldendal, Oslo (2012).
6. Spadorcia, S. A.: Examining the text demands of high-interest, low-level books. Reading & Writing Quarterly 21(1), 33-59 (2005).

7. Rello, L., Baeza-Yates, R.: Good fonts for dyslexia. In: Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 1-8. ACM, Bellevue, Washington, (2013).
8. O'Brien, B. A., Mansfield, J.S., Legge, G.E.: The effect of print size on reading speed in dyslexia. Journal of Research in Reading 28(3), 332-349 (2005).
9. Zorzi, M., et al.: Extra-large letter spacing improves reading in dyslexia. Proceedings of the National Academy of Sciences 109(28), 11455-11459 (2012).
10. Rello, L., et al.: Size matters (spacing not): 18 points for a dyslexic-friendly Wikipedia. In: Proceedings of the 10th International Cross-Disciplinary Conference on Web Accessibility, pp. 1-14. ACM: Rio de Janeiro, Brazil (2013).
11. Rello, L., Baeza-Yates, R.: How to present more readable text for people with dyslexia. Universal Access in the Information Society 16(1), 29-49 (2017).
12. Schneps, M.H., et al.: Shorter lines facilitate reading in those who struggle. PLOS ONE 8(8), e71161 (2013).
13. Perez, T.M., et al.: Functional alterations in order short-term memory networks in adults with dyslexia. Developmental Neuropsychology 40(7-8), 407-429 (2015).
14. Starr, M. S., Rayner, K.: Eye movements during reading: some current controversies. Trends in Cognitive Sciences 5(4), 156-163 (2001).
15. Lindkvist, E.: Ditt røde hår, Unn [Your red hair, Unn]. Solum, Oslo (2013).
16. Jackson, M. D., McClelland, J. L.: Processing determinants of reading speed. Journal of Experimental Psychology: General 108(2), 151-181 (1979).
17. Sabatini, J. P.: Efficiency in Word Reading of Adults: Ability Group Comparisons. Scientific Studies of Reading 6(3), 267-298 (2002).
18. Perfetti, C.: Reading ability: Lexical quality to comprehension. Scientific Studies of Reading 11(4), 357-383 (2007).
19. Ryder, D., B. Norwich: What's in a name? Perspectives of dyslexia assessors working with students in the UK higher education sector. Dyslexia, 24(2), 109-127 (2018).
20. Peterson, R. L., Pennington, B. F.: Developmental Dyslexia. Annual Review of Clinical Psychology 11(1), 283-307 (2015).
21. Mortimore, T., Crozier, W.R.: Dyslexia and difficulties with study skills in higher education. Studies in Higher Education 31(2), 235-251 (2006).
22. Snowling, M. J.: Dyslexia. Blackwell, Oxford (2000).
23. Thiessen, M., Dyson, M. C.: Typography for children with reading difficulties: Preferences for type in reading books. International Journal of the Book 6(2), 115-122 (2009).
24. Berget, G., Fagernes, S.: “I’m not stupid” - Attitudes towards adaptation among people with dyslexia. In: Masaaki, K. (ed.) Human-Computer Interaction: Theories, Methods, and Human Issues, pp. 237-247. Springer, Cham (2018).
25. Brante, E. W.: ‘I don't know what it is to be able to read’: How students with dyslexia experience their reading impairment. Support for Learning 28(2), 79-86 (2013).
26. Iwarsson, S., Ståhl, A.: Accessibility, usability and universal design—positioning and definition of concepts describing person-environment relationships. Disability and Rehabilitation 25(2), 57-66 (2003).
27. Story, M. F., Mueller, J. L., Mace, R. L.: The universal design file: Designing for people of all ages and abilities. Center for Universal Design, Raleigh (1998).

28. UN: Convention on the rights of persons with disabilities (2006), https://www.un.org/disabilities/documents/convention/convoptprot-e.pdf, last accessed 2021/01-25.
29. Bal, P. M., Veltkamp, M.: How does fiction reading influence empathy? An experimental investigation on the role of emotional transportation. PLoS ONE 8(1), 1-12 (2013).
30. Mol, S. E., Bus, A. G.: To read or not to read: A meta-analysis of print exposure from infancy to early adulthood. Psychological Bulletin 137(2), 267-296 (2011).
31. Gambrell, L. B.: Seven rules of engagement: What's most important to know about motivation to read. The Reading Teacher.65(3), 172-178 (2011).
32. Schunk, D. H., Zimmerman, B.J.: Social origins of self-regulatory competence. Educational Psychologist 32(4), 195-208 (1997).
33. Carawan, L. W., Nalavany, B.A., Jenkins, C.: Emotional experience with dyslexia and self-esteem: the protective role of perceived family support in late adulthood. Aging & Mental Health 20(3), 284-294 (2016).
34. Humphrey, N.: Teacher and pupil ratings of self-esteem in developmental dyslexia. British Journal of Special Education 29(1), 29-36 (2002).
35. Riddick, B., et al.: Self-esteem and anxiety in the educational histories of adult dyslexic students. Dyslexia 5(4), 227-248 (1999).
36. Alexander-Passe, N.: How dyslexic teenagers cope: An investigation of self-esteem, coping and depression. Dyslexia 12(4), 256-275 (2006).
37. Becker, M., McElvany, N., Kortenbruck, M.: Intrinsic and extrinsic reading motivation as predictors of reading literacy: A longitudinal study. Journal of Educational Psychology 102(4), 773-785 (2010).
38. Leinonen, S., et al.: Heterogeneity in adult dyslexic readers: Relating processing skills to the speed and accuracy of oral text reading. Reading and Writing 14(3), 265-296 (2001).
39. Wolf, M., Katzir-Cohen, T.: Reading fluency and its intervention. Scientific Studies of Reading 5(3), 211-239 (2001).
40. Daneman, M., Carpenter, P. A.: Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behavior 19(4), 450-466 (1980).
41. Rayner, K., et al.: Psychology of Reading. Psychology Press, New York (2012).
42. Burton, C., Daneman, M.: Compensating for a limited working memory capacity during reading: Evidence from eye movements. Reading Psychology 28(2), 163-186 (2007).
43. Samuels, S.J., Eisenberg, P.: A framework for understanding the reading process. In Pirozzolo, F. J., Wittrock, M. C. (eds.): Neuropsychological and cognitive process in reading. Academic Press: New York (1981).
44. Jackson, J. E.: Towards universally accessible typography: A review of research on dyslexia. Journal on Technology & Persons with Disabilities 2 (2014).
45. Myrberg, C. Wiberg, N.: Screen vs. paper: What is the difference for reading and learning? Insights. 28(2), 49-54 (2015).
46. Schneps, M.H., et al.: E-Readers are more effective than paper for some with dyslexia. PLOS ONE 8(9), e75634 (2013).
47. Kretzschmar, F., et al.: Subjective impressions do not mirror online reading effort: Concurrent EEG-Eyetracking evidence from the reading of books and digital media. PLOS ONE 8(2), e56178 (2013).
48. Benedetto, S., et al.: E-Readers and visual fatigue. PLOS ONE 8(12), e83676 (2013).

49. Mangen, A., Walgermo, B. R., Brønnick, K.: Reading linear texts on paper versus computer screen: Effects on reading comprehension. International Journal of Educational Research 58, 61-68 (2013).
50. British Dyslexia Association: Dyslexia style guide, http://www.bdadyslexia.org.uk/common/ckeditor/filemanager/userfiles/About_Us/policies/Dyslexia_Style_Guide.pdf, ast accessed 2021/01/13.
51. Rello, L., Baeza-Yates, R.: The effect of font type on screen readability by people with dyslexia. ACM Transactions on Accessible Computing 8(4), 1-33 (2016).
52. Hillier, R.: Sylexiad. A typeface for the adult dyslexic reader. Journal of Writing in Creative Practice 1(3), 275-291 (2008).
53. Boer, C. T. Font Dyslexie 2017, https://www.dyslexiefont.com/en/typeface/, last accessed 2020/12/13.
54. Marinus, E., et al.: A special font for people with dyslexia: Does it work and, if so, why? Dyslexia 22(3), 233-244 (2016).
55. Ling, J., van Schaik, P.: The influence of font type and line length on visual search and information retrieval in web pages. International Journal of Human-Computer Studies 64(5), 395-404 (2006).
56. Davidov, A.: Computer screens are not like paper: Typography on the web. In: Sassoon, R. (ed.): Computers & Typography. Intellect: Bristol (2002).
57. Bernard, M.L., et al.: The effects of line length on children and adults' perceived and actual online reading performance. Proceedings of the Human Factors and Ergonomics Society Annual Meeting 47(11), 1375-1379 (2003).
58. ISO: ISO 8596 Ophthalmic Optics: Visual Acuity Testing – Standard Optotype and its Presentation. ISO, Geneva 2009.
59. Zhang, P., et al.: Binocular balance in normal vision and its modulation by mean luminance. Optometry and Vision Science 88(9), 1072-1079 (2011).
60. Høien, T., Tønnesen, G.: Ordkjedetesten [The Word Chain Test]. Logometrica, Bryne (2008).
61. Nomura, M., Nielsen, G. S., Tronbacke, B.: Guidelines for easy-to-read materials. IFLA Professional Reports 120. International Federation of Library Association and Institutions, The Hague 2010.
62. McCarthy, J. E., Swierenga, S. J.: What we know about dyslexia and Web accessibility: A research review. Universal Access in the Information Society 9(2), 147-152 (2010).
63. Santana, V. F. d., et al.: Web accessibility and people with dyslexia: A survey on techniques and guidelines. In Proceedings of the International Cross-Disciplinary Conference on Web Accessibility, pp. 1-9. ACM, Lyon, France 2012.